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September 2010

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The next great space telescope takes shape

Launching in 2014, the Webb scope will explore galaxies and exoplanets like never before p. 24

How to find galaxies online with Galaxy Zoo p. 30

See Jupiter at its best in September p. 50

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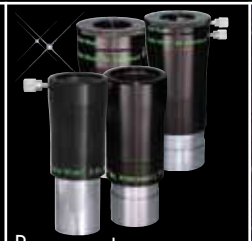
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and here's what they can do . . .

AT8IN image of the Horsehead and Flame nebulae in HaRGB by astronomy hobbyist David Rosenthal (http://pbase.com/djrlx90). See the much larger uncropped full-color image at his website.

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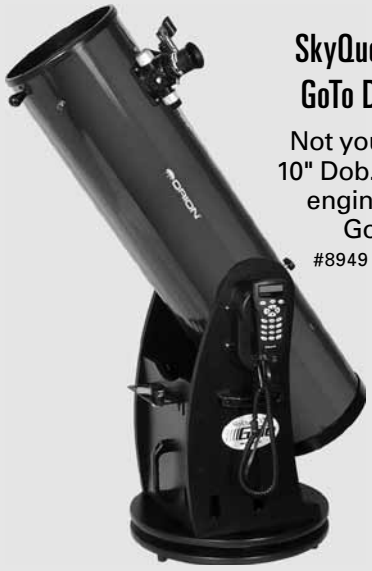

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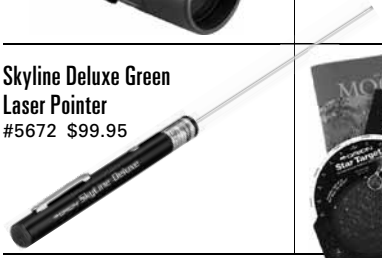

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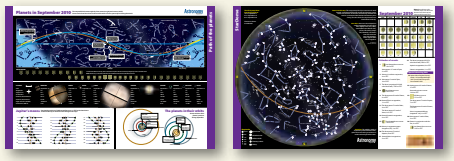


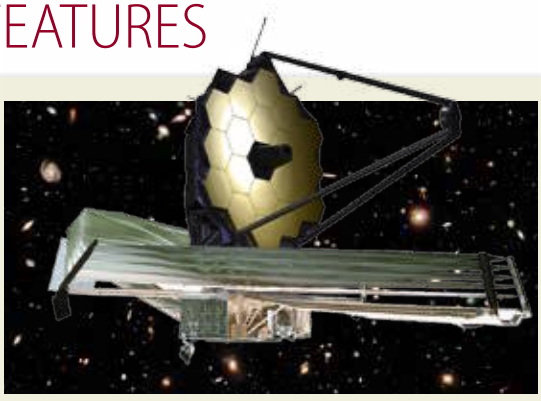
Path of the planets and StarDome.

Cover: Telescope: NASA/GSFC/JWST; Background: NASA/ESA/STScI

ON THE COVER

The 6.5-meter Webb telescope will probe the farthest galaxies, examine exoplanet atmospheres, and peer deep into star-forming regions such as the Carina Nebula.

FEATURES



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The next great space telescope takes shape
Once it launches, the James Webb telescope will explore distant galaxies, stellar nurseries, and exoplanet atmospheres in detail no ground-based observatory can touch. **FRANCIS REDDY**

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Ordinary people classifying galaxies makes one of the world's most enjoyable citizen science projects also one of the most successful. **WILLIAM KEEL**

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Jupiter rules the night. **MARTIN RATCLIFFE AND ALISTER LING**

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If Galileo could see us now, what would he think about our study of the cosmos? **CHRIS IMPEY**

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Amateur astronomers take note: You might want to add these 35 products to your holiday wish list.
PHIL HARRINGTON

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With the giant planet bigger and brighter than it's been in more than a decade, let the cry go forth: It's Jupiter time!
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WEB EXTRA

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This Month in *Astronomy*

Astronomy's Star Products and our photo contest, too

by David J. Eicher

I'm delighted to announce a new magazine feature, *Astronomy*'s Star Products. This annual special award feature story (see pages 52 through 59) will showcase each year's hottest, most innovative, and most noteworthy telescopes, cameras, eyepieces, software, and accessories that will keep your backyard astronomy experience on the cutting edge. This year, longtime *Astronomy* Contributing Editor Phil Harrington presents 35 featured products for you to consider. They represent goods from 21 manufacturers and range from a simple $49.95 Celestron FirstScope to several substantial items that run several thousand dollars apiece.

Congratulations to all the companies who earned *Astronomy* Star Product recognition this year.

***Astronomy*'s 2010 Astroimaging Contest**

I also have the great pleasure to announce *Astronomy*'s 2010 Astroimaging Contest. This annual contest is open for entries now through October 1, 2010. We invite you to submit your finest astroimage you have taken at www.Astronomy.com/photocontest. You can also send your digital image on a CD or DVD to: *Astronomy* Photo Contest, P.O. Box 1612, Waukesha, WI 53187-1612. Each image must feature an astronomical subject in one of three categories: Deep-Sky, Solar System, or General. One entry per contestant is allowed. Composite images (those made from multiple exposures) are allowed. Please include a description of the subject featured, the name and address of the imager, equipment used, and exposure time(s). No images/disks will be returned.

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The telescope's mount features NexStar computer control technology, a database of 40,000 objects, customizable database lists of the most famous deep-sky objects by name and catalog number, and a newly redesigned drive base and drive mechanics.

For more details on this and other Celestron scopes, see www.celestron.com.

Winners of the three categories in the astroimaging contest will win a CCD camera from Imaging Source (see www.astronomycameras.com). The first is the DMK 31AU03.AS camera, a monochrome USB camera with a resolution of 1024x768 pixels and a 1/3" progressive scan CCD. The second is the DMK 41AU02.AS camera, a 1/2" progressive scan CCD with a resolution of 1280x960 pixels. The third is the DMK 21AU04.AS camera, a 640x480 pixel camera with 1/4" progressive scan CCD. Each of these will provide the winners with years of quality skyshooting.

So get out there, shoot some images, and send them in, and you may come away a big winner!

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 38, Number 9

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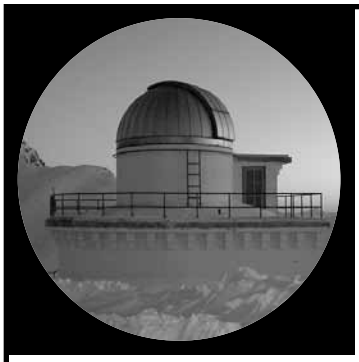

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NEAF a grand time

Thank you for providing the Northeast Astronomy Forum (NEAF) trip to me as the winner of *Astronomy*'s Youth Essay Contest. It was incredible! Everyone — *Astronomy* magazine personnel, vendors, speakers, and even other attendees — was extremely gracious and helpful. It never ceases to amaze me how everyone in the astronomical community is always so willing to share their invaluable expertise.

The vendors offered superb advice on the eyepieces and filters that I was considering. Many spent considerable time explaining my options and helping me optimize my budget.

Attending amateur astronomers also offered friendly advice. On one occasion, I was debating between two eyepieces and an amateur astronomer who happened to own one of my choices overheard my indecisiveness. He gave me a firsthand review and addressed all of my concerns.

In addition, the speakers were extremely informative and were available after their lectures to sign autographs and answer questions. Even the keynote speaker, Alex Filippenko of the University of California, Berkeley, stayed for almost an hour after his presentation to answer questions, shake hands, and sign autographs for the audience.

Our Youth Essay Contest winner, Adam Atanas, met astrophysicist Alex Filippenko at the Northeast Astronomy Forum (NEAF). Atanas won the trip to April's NEAF. Katya Atanas

The *Astronomy* staff introduced me to various people who could answer my questions, and they even arranged a dinner with Dr. Filippenko. I sincerely appreciate this amazing opportunity from *Astronomy* magazine. The event absolutely exceeded my expectations. Thank you. **— Adam Atanas,** Houston, Texas

Get involved

In Bob Berman's April 2010 "Strange Universe" column, he wrote, " 'See that bright star? It's Jupiter!' is enough to hook any kid. But too often, no one starts them down that road." We amateur astronomers can do a great deal to engage children in astronomy. One way is by teaching astronomy in schools during after school programs, especially in urban areas where there are large numbers of minority youth who have little access to dark skies.

As an amateur astronomer, I have been teaching astronomy in after-school programs for 7 years. It's terrifically rewarding, and the kids love it. Not all will become amateur or professional astronomers, but some will. And all come away with an appreciation of astronomy that every adult should have.

It may seem a daunting task to find a school, develop a curriculum, and manage a classroom, but most of the work has been done for you by the nonprofit Citizen Schools (www.citizenschools.org). Not only do they provide a curriculum and training, but they also pair you with students and a staff member to assist with the class. All you need to bring is your love of astronomy. **— Tony Helies,** Weston, Massachusetts

Please be true to view

I enjoyed Phil Harrington's article in the May 2010 issue titled "10 top summer binocular treats." However, I feel that the pictures in this article, as with so many other stories in the magazine, are not representative of what the average amateur astronomer is going to see through binoculars or a telescope. In an article about popular binocular targets, it does a disservice to binocular fans to include pictures of the objects obviously taken with digital cameras. They show an image that is nothing like what the observer will see when using the equipment proposed in the article.

Perhaps we need more use of pencil sketches, as Editor David J. Eicher does with his "Deep-sky Showcase." These are realistic. I am a new observer, although old in years, and I may be a very "typical" subscriber/observer who finds it disappointing when the articles use photos that have nothing to do with reality at the eyepiece. **— Dan Ostler,** Ajax, Ontario

By the act of their creation, time-exposure photos of astronomical objects always go beyond what observers see in binoculars or a telescope. They collect more light than the human eye and so show more stars and more detail in nebulosity, although they do capture less dynamic range than the human eye does. Sketches often do a good job of approximating what observers see, but they often present the numerous details of an eyepiece view somewhat differently than they really are. So there's no easy answer to show, graphically, exactly how a binocular view appears to the human eye. To make everyone as happy as possible, we'll continue to offer a mixture of photos and sketches. **— David J. Eicher,** Editor

Correction

In Michael E. Bakich's "Fun observing the Sun" (May 2010), the first sentence of the last paragraph in the "Pick a viewing method" section is incorrect. The chromosphere is the layer above the visible surface, not below. **— *Astronomy* Editors**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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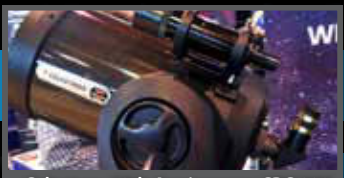
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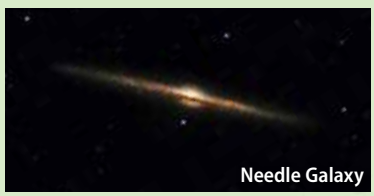
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by Bob Berman

Cool expressions

Astronomy's most interesting concepts are often named after the peculiar surnames of their discoverers.

The greatest honor for an astronomer is to have his or her name emblazoned in the heavens. We'll forever speak of Cassini's Division, the main gap in Saturn's rings. Or the Kuiper Belt of distant ice balls. Some names, like KY-per, are not intuitive to pronounce. Others are controversial. Scholars still debate whether it's HAW-leez Comet or HAL-eez. Most folks still enunciate it like the 1950s group Bill Haley (HAY-lee) and his Comets.

Naïve friends occasionally ask, "Do you think you'll ever discover something that they'll name after *you*?" And of course I tell them it's mostly comet-hunters like David H. Levy who get their names etched into the sky. I merely popularize the hard work of other researchers.

But perhaps I can finagle some other kind of discovery. For example, I've noticed that during banquet lectures, when everyone's blood is pulled from their brains for digestion, audience questions get strange. An actual example: "If the Sun is a star, why can't we see it at night?" Maybe someday people will refer to stupid questions after a banquet dinner as the *Berman Outcome*.

An easy name is a pleasure. Tom Bopp, a great guy, lectured with me on a cruise ship in 1997. He was an amateur astronomer with a bad back, taking a break from his jewelry business, when he discovered the largest comet of the century. But we most appreciated his name because a string of comet tongue twisters had been plaguing the sky. The previous year's spectacle was the sadistic Hyakutake (for the record, it's YAH-koo-TAH-kee).

Pronunciation isn't everything, of course. A label should also sound cool, with a snap, a resonance. Like the Parker spiral, the shape of the Sun's magnetic field. Or the Purkinje effect (poor-KIN-yeh). I try to say that one as much as possible, even when it's not appropriate. Jan Purkinje discovered that, in faint light, our eyes most easily see green-blue. This explains the bizarre reality that a white Full Moon makes the countryside turquoise. All the autumn oranges and reds are out there, but our eyes don't see them. Neat.

Sometimes a person vanishes and yet his name lingers on like a Cheshire Cat's smile. We love Cassegrain telescopes but who the heck was Guillaume (also known as Laurent) Cassegrain, who designed it in 1672? Nothing is known about him.

What about the Zeeman effect? In 1896, a Dutch school teacher, Pieter Zeeman, was forbidden by his superiors to use the lab alone. He disobeyed them, snuck in, and discovered that magnetism makes spectral lines split. Bingo — an easy way to detect magnetism in stars.

"Do you think you'll ever discover something that they'll name after *you*?"

As a reward for this world-class finding, the school fired him. But the Zeeman effect quickly became all the rage, and he accepted a far better job at double the pay. There's even a postscript to this heartwarming revenge story. His friend and mentor Hendrik Lorentz (another great name), upon hearing of the Zeeman business, brilliantly deduced that all light must be created solely by the motion of a tiny object with a negative charge. He consequently predicted the first-ever particle, the electron, 3 years before its discovery. A happy ending: Lorentz and Zeeman shared the 1902 Nobel Prize in physics.

Multiple names can sound especially impressive, like the Poynting-Robertson effect. Mention that one at your next party. A century ago, John Poynting and Howard Robertson realized that the pressure of sunlight robs energy from tiny orbiting objects, making them spiral toward the Sun. It explains why meteor showers don't last forever. Rather, those meteoroids pass through our orbit for a bunch of centuries, and then shuffle sunward, never to be encountered again.

How about Milankovitch cycles? I'm sorry I didn't name my daughter Milutin Milankovitch. That Serb explained ice ages. Milutin showed that changes in our orbit's shape, and our axis tilting back and forth from 22° to 24.5° and changing direction, all affect the Sun's effect on Earth. Together, they create our climate cycles. Very crisp.

Milutin. I'm going to start using the byline Milutin. Yet there are so many other great tags. Some are utterly esoteric, like the Mohorovičić discontinuity. (Hint: It's a few miles beneath the ocean floor.) Others have amazing meanings, like Cerenkov radiation — the eerie blue glow emitted by an object moving faster than light. It can happen anywhere except in a vacuum, like space. Or the Tully-Fisher relation, a clever way to find the distance to galaxies. Or the Roche limit, the place where a spiraling-in moon breaks into pieces and becomes a ring.

And it's not just limits, cycles, or effects that have names attached to them. Would you believe beads, belts, and clouds? We've got the Van Allen belt, the Magellanic Clouds, Kepler's laws, Baily's beads, Domino's Pizza — it's endless.

And all I'll ever get is the *Berman Outcome*, which measures idiocy.

Browse the "Strange Universe" archive at www.Astronomy.com/Berman.

Contact me about my strange universe by visiting **skymanbob.com.**

by Glenn Chaple

Engaging astronomy's teens

How do we get teenagers excited about astronomy in this digital age?

A lyric from an early 1960s anti-war song laments: "Where have all the young men gone?" Add the words "and women," and you describe the current plight of amateur astronomy. Teens seem to be especially absent from star parties and astronomy groups.

Not long ago, I received an e-mail from Anthony Kyle, a 10-year-old who lives in Perrysburg, Ohio. Anthony had received a telescope for Christmas and was anxiously looking forward to using it to explore the night sky. He even started a newsletter called *The Astronomer*. Another e-mail came from 12-year-old Katie Fleming of Dubuque, Iowa. Katie also owns a telescope and hopes to use it to take digital photographs of the Moon. She aspires to be a NASA astronaut some day.

Anthony and Katie aren't alone. Many youngsters ages 8 to 12 are openly enthusiastic about astronomy. Unfortunately, we lose many of them once they enter their teens.

Science educators in the upper grade levels frequently are reluctant to teach astronomy. Too often, the introductory astronomy courses these teachers took in college were bogged down with complicated formulas and abstract concepts, and they either repeat the mistakes of their professors or avoid teaching the subject altogether.

Breathing life into an astronomy course doesn't mean having to water it down. Andrew Fraknoi, a veteran instructor and former executive director of the Astronomical Society of the Pacific (ASP), teaches an introductory astronomy class at Foothill College near San Francisco. Here's an example of how he handles the sometimes sleep-inducing topic of astronomical history: "I try to tell some humorous anecdotes from the history of astronomy, such as James Lick funding the Lick Observatory only after being talked out of his first choice for a memorial, which was to construct the world's largest pyramid in downtown San Francisco, or Edwin Hubble being told by his father that astronomy was not an acceptable pursuit for a young man who wanted to make something of himself."

Anthony Kyle, age 10, and Katie Fleming, age 12, are both astronomy enthusiasts with their own telescopes and space-related dreams. The challenge the hobby faces today is keeping kids like them excited about astronomy through their teen years. Jacqi Kyle and Katie Fleming

Another stumbling block for teenagers is "nerd fear." Plunking down a telescope in the backyard, they worry, might be a one-way ticket to the Kingdom of Geekdom. Mike Kertyzak is an example. As a student in my eighth-grade science class 20 years ago, he didn't seem interested in my astronomy unit. But not long ago, I got an e-mail from Mike, who had come across one of my articles in *Astronomy*. Now an adult, he is an avid amateur astronomer. Mike admits that he was always fascinated with astronomy but didn't want to look "uncool" by openly demonstrating that interest in class.

Arguably the most pervasive roadblocks to youth involvement in astronomy are computers and video games. The typical teenager would much prefer playing Mario on a Wii to standing outside in the chilly night air with a telescope. One solution is to fight technology with technology. While traditionalists enjoy peering through the eyepiece, modern-day astronomy is far more high-tech. Images from remote robotic telescopes are relayed to a computer where observers can examine them. Such cutting-edge astronomy might prove exciting to a high-schooler who likes computer games.

How do we limit the drop-out rate for teenage astronomers? The best way is through community outreach. Offer to conduct star parties for local middle and high schools. Help institute an after-school astronomy club. Share your astronomy expertise with classroom teachers and the public through programs like Project ASTRO and the Night Sky Network, both sponsored by the ASP. Project ASTRO augments astronomy education by training volunteer astronomers and pairing them with local educators. The Night Sky Network offers outreach material kits for clubs that want to engage the public and spread the word about astronomical discoveries. Check out the ASP's educational section (www.astrosociety.org/education.html) for more information and a veritable treasure-trove of resources.

Those of us devoted to the wonder and mystery of a star-filled sky should do whatever we can to pass that legacy on to our teens. Who knows, if we keep them interested, some day we may read an article in *Astronomy* written by Anthony Kyle or gaze upward to see an orbiting space station, knowing that astronaut Katie Fleming is onboard.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com.

Read about Andrew Fraknoi's teaching methods at www.Astronomy.com/toc.

SecretSky

by Stephen James O'Meara

The "Red Region"

Fall is the season of warm red hues, both on Earth and among the stars.

As fall approaches, many in temperate latitudes look forward to watching the leaves turn color, from drab green to mixed shades of yellow, orange, and red. The fall stars have something in common with autumn leaves, for they too are rich in warm hues. But you must know where to look.

The 19th-century Irish astronomer John Birmingham called attention to this curiosity in his "The Red Stars: Observations and Catalogue," published in the 1879 *Transactions of the Royal Irish Academy*. Aside from his own plentiful observations, the catalog incorporated those of Danish astronomer Hans Schjellerup (who had compiled a catalog of red stars in 1866) and others, for a total of 658 red and orange stars.

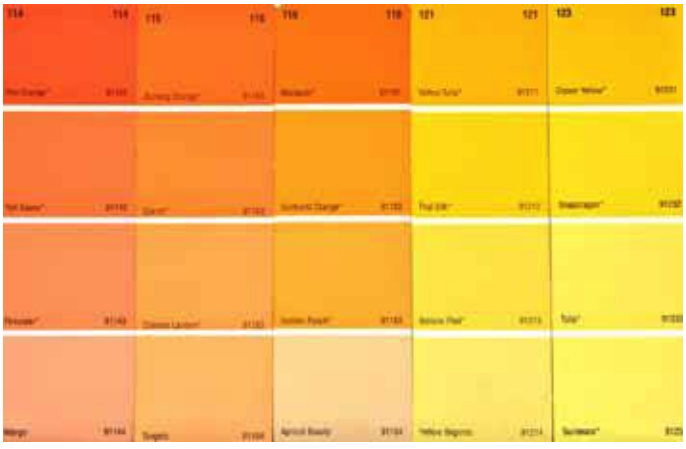
In the introduction, Birmingham notes that a "space of the heavens including the Milky Way, between Aquila, Lyra, and Cygnus, seems so peculiarly favored by red and orange stars that it might not inaptly be called the Red Region."

In September, the Red Region luckily lies well above the southern horizon after sunset. This month I've spotlighted a select group of its colored gems. To help tune your color sensitivity, I've chosen stars that warm sequentially through the following spectral classes: G (yellow), K (orange), M (red), and the rare carbon class C (deep red). Astronomers further subdivide these classes from 0 to 9; a G8 star, for instance, looks closer to orange than yellow, and a K5 star is midway between orange and red. But what color you see is unknown — until you look.

Effective seeing

Everyone sees color differently, so don't rely on the star's spectral type for a definitive visual hue. Consider the striking, colorful double star Albireo (Beta [β] Cygni) in Cygnus. Observers have described its magnitude 3.1 K3 primary as yellow, topaz, gold, and orange; its magnitude 5.1 type B9 (blue-white) secondary (34" away) can appear deep-blue, azure, sapphire, or green.

Perceived color is not only highly subjective, but it can also be a product of physiological and psychological effects (such as strong contrasting colors, as in the case of a double like Albireo). Star color also depends on atmospheric conditions: Dust and pollutants will redden a star's hue. Also, stars close to the horizon will appear redder than those higher in the sky, just like the Sun does at sunset.



When looking at solitary stars, most people can differentiate fewer than a dozen colors. To help increase your star-color vocabulary, the author suggests using ColorPlace paint swatches available at Walmart. The swatches come in a rich variety of sometimes exotic colors, including Apricot Beauty, Crown Yellow, Firewater, and Burning Orange. Stephen James O'Meara

Warming up

We'll begin our search with magnitude 4.4 Sham, the Alpha (α) star of Sagitta the Arrow. To me, Sham (G1) has a lemon-yellow sheen. The color becomes even more conspicuous when I compare it to that of the similarly bright G8 star Beta Sagittae, which lies only 35' to the south-southeast. Both Sham and Beta are yellow giants. But when I look at Beta through binoculars, its color appears a tad warmer, like that of a squash. Can you detect a difference?

Now lower your gaze about 10° to magnitude 0.8 Altair in Aquila the Eagle. Two colorful naked-eye companions flank Altair: magnitude 3.7 Alshain (Beta Aquilae), 2.7° to the south-southeast; and magnitude 2.7 Tarazed (Gamma [γ] Aquilae), 2° to the northwest. All three stars fit comfortably in the same binocular field of view. While spectral type A Altair shines like a sparkling blue-white diamond, I find Alshain (G8) has a banana-peel yellow hue and Tarazed (K3) has more of a golden sheen.

Use this star chart to find the variable stars R and T Lyrae, which lie about 6° northeast and 2° southwest of Vega (Alpha [α] Lyrae), respectively. R varies in brightness from magnitude 4 to 5 and back every 46 days. T Lyrae varies irregularly in brightness, from magnitude 7.5 to 9.3. *Astronomy:* Roen Kelly

Note that Alshain and Beta Sagittae have the same spectral characteristics, as do Tarazed and Albireo's brighter component. Do the stars of the same spectral type appear the same color to you? I find Beta Sagittae looks slightly deeper yellow than Alshain; it's hard for me to discern any difference between Tarazed and the yellow star in Albireo.

Now return to Sagitta and look at magnitude 3.5 Gamma, the tip of the celestial Arrow. One of the sky's few naked-eye red giants, it used to be classified as a K5 star, but now it's listed as a type M0 giant. Gamma's light appears deeper than Beta Sagittae's through binoculars, closer to a pumpkin's color.

Chameleon stars

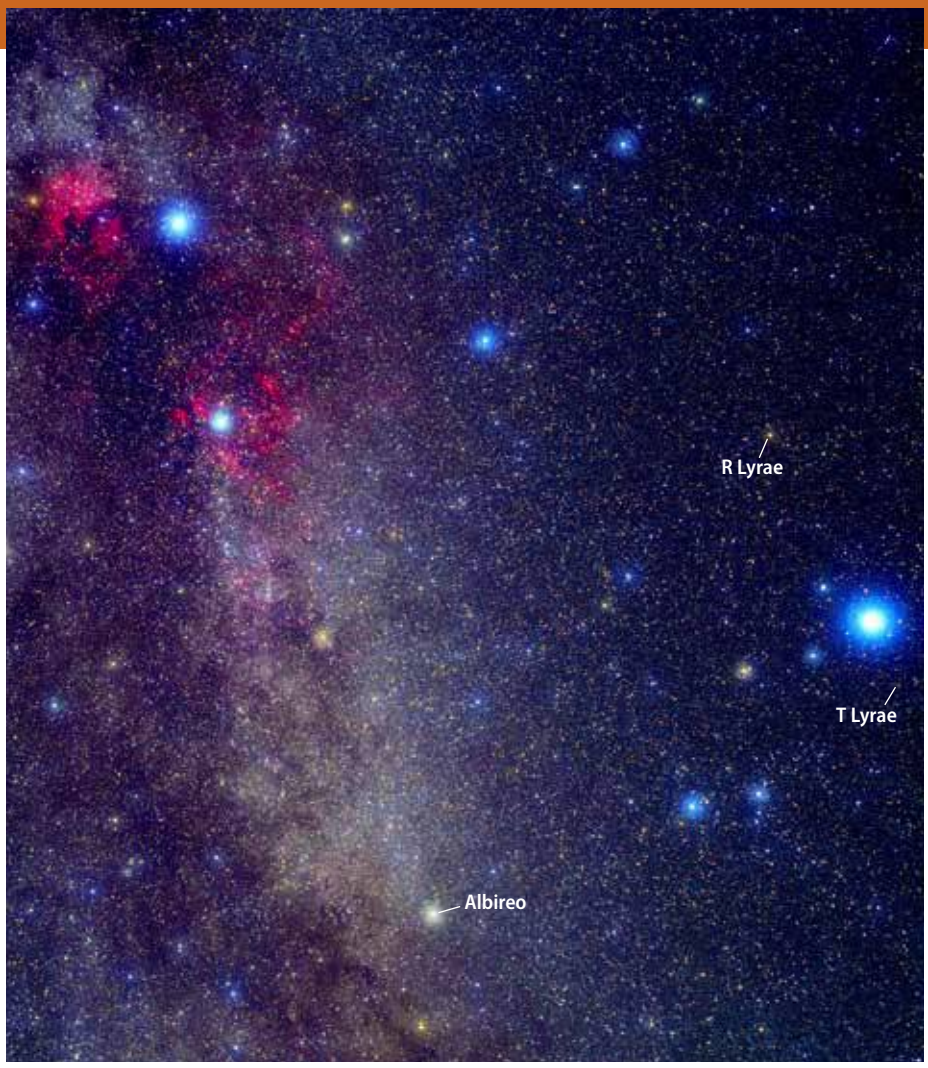
Next, look at variable star R Lyrae, about 6° northeast of Vega. Also known as 13 Lyrae, it is a naked-eye red giant of spectral class M5. The star fluctuates in brightness — between magnitude 3.9 and 5.0 — over a period of 46 days, so it never dips below naked-eye visibility. Through 10x50 binoculars, I find the star has a rich orange hue.

Through a telescope, however, R Lyrae's color seems to pale. Indeed, the 19th-century British astronomer Admiral William Henry Smyth (who had a penchant for seeing exotic star colors through his telescope) recorded R Lyrae as appearing "bright yellow." In his own observations of red stars, Julius Schmidt (1825–1884), director of Athens Observatory, noticed that red variable stars grow paler as they increase in magnitude and become more ruddy as they again decrease toward their minimum. Birmingham also noted the same phenomenon. Watching these stars pulsate over time is like watching a leaf change colors in the fall.

I too have found that the color of bright binocular stars visually "cools down" a bit in a telescope's eyepiece; each increase in telescopic magnification also lessens the intensity of the view. Interestingly, this same phenomenon occurs with naked-eye Mars: When far away, Mars appears like a crimson spark, but when near, it has a golden hue.

Finally, turn your telescope to demonred T Lyrae, a rare type of red giant variable star rich in carbon (it is, in fact, a carbon star), whose compounds absorb blue light effectively. T Lyrae is classified as a C6,5 star: The first number refers to the star's temperature on a scale of 0 to 9, with 9 being at the cool end; the second number refers to how red the star appears on a scale of 1 to 5, with 5 being the reddest. T Lyrae is, in fact, one of the reddest stars in the sky. When brightest, it shines at magnitude 7.5; when faintest, it's at magnitude 9.3, so a telescope is best for watching its irregular pulsations.

As always, share your observations with me at someara@interpac.net.



Part of John Birmingham's "Red Region" is on display here, as Albireo, R Lyrae, and T Lyrae show off their autumnal colors. When searching for such stars, remember that although we refer to a star's color as "warming" toward the red, the star's temperature is just the opposite; as the saying goes, "Red giants aren't so hot!" Bill and Sally Fletcher

The wide variety of colors around Sagitta the Arrow, part of the "Red Region," is on full display in this color photo, taken by the author. The stars are intentionally slightly out of focus, which makes the colors easier to discern; amateurs can try this technique through binoculars or telescopes. Stephen James O'Meara

Read "Tour the sky's reddest stars" from *Astronomy*'s December 2007 issue at www.Astronomy.com/toc.

by David H. Levy

Dr. David Levy-Shakespeare

A journey in education concludes, but the journey of learning continues.

As my wife, Wendee, and I enjoyed the Olympic hockey final February 28, the Senate of the Hebrew University of Jerusalem formally approved my doctoral thesis. With relief, we learned that I am now officially a Doctor of Philosophy. This process brings a close to my formal education, which has lasted, on-and-off, for 58 years. I remember being called a slow poke back in nursery school, and now I've slowly poked my way to a doctorate.

I thought I was done when I got my master's degree from Queen's University in Kingston, Ontario, in 1979. My thesis, "The Starlight Night," broke new ground on the connection between the night sky and English literature, a topic long close to my heart. My adviser, Dr. Norman MacKenzie, eased my path by pointing out a wonderful poem by Gerard Manley Hopkins called "I am like a slip of comet." I deduced that Comet Tempel-Respighi must have inspired Hopkins because it had passed between two bright stars, Iota Aurigae and Beta Tauri, just 2 weeks before Hopkins penned his verse. Those 19 lines were the heart of my work at that time.

After earning my master's degree, I relocated to Tucson, Arizona, planning to live there until I discovered a comet. Thirty-one years, 23 comets, and one wife later, I still thoroughly enjoy my life here. But about 5 years after I arrived, a thought entered my brain: Are you going to finish what you started and earn a Ph.D.? Right away, I stomped this idea down, but every 5 years or so, the same thought would resurface, and I would bury it again.

Hebrew University of Jerusalem's humanities library, left, is an imposing structure on the Mount Scopus campus. The university houses Albert Einstein's telescope, pictured in front of Minerva, one of the author's oldest scopes. David H. Levy

This process of denial continued until about 2000, when Wendee suggested we discuss it seriously. She believed that I should indeed finish what I had started, and so we began a search for a topic and the right university. In the fall of 2001, I began remote studies at the Hebrew University of Jerusalem to study under Dr. Lawrence Besserman the subject of the night sky during English literature's early modern period. I further narrowed the period to the era between 1572 (when Tycho's great supernova erupted in the northern sky) and 1620, a period including the literary responses of John Donne and others to early uses of the telescope.

Getting the proposal approved took almost a third of the 9 years, but then the fun part began. Most of that time I did research, first investigating literary references to the two supernovae that punctuated Shakespeare's time: Besides Tycho's star in Cassiopeia, his student, Kepler, recorded a second one in Ophiuchus in 1604 that, at its best, outshone Jupiter. I then meandered over to the parade of comets, all necessarily visible to the naked eye in this pre-telescopic era, that brightened Shakespeare's sky.

In 2007, I suffered a stroke while completing the chapter on eclipses, but with unceasing support from my wife at home and Dr. Besserman in Israel, I plodded onward, completing a draft of the thesis in 2008 and the final text in 2009. We spent much of the first 2 months of this year going through every word, comma, and space.

Just as with comet hunting, surprise discoveries provided the most fun during this enterprise. My most satisfying discovery came one night in August 2009: While scanning through Shakespeare's lines in *Edward III*, I found this gem, in which the terrified king of France observes:

A sudden darkness hath defaced the sky,
The winds are crept into their caves for fear,
The leaves move not, the world is hushed and still,
The birds cease singing ...

I cannot imagine any better description of the land during a deep partial or a total eclipse of the Sun. The only problem is that by 1595, the Bard could not have seen a deep partial solar eclipse. Shakespeare might have gleaned the idea from a traveler's tale heard in a pub of an eclipse in the Atlantic Ocean, or from Raphael Holinshed's *Chronicles*, which mentions several eclipses.

The Scottish play, *Macbeth*, also mentions eclipses when, after Duncan's murder, Ross says, "By th' clock 'tis day, / And yet dark night strangles the travelling lamp." This is a clear reference to the near-total eclipse Shakespeare could have witnessed in October 1605.

More than anything else, these past 9 years have taught me that great literature grows more inspiring and magnificent with an understanding of the natural world, especially the oft-overlooked but always impressive sky.

Browse the "Evening Stars" archive at www.Astronomy.com/Levy.

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Too cool A paper in the May 13 *Nature* shows how a new theory of white dwarf cooling resolves an age conflict for the open star cluster NGC 6791.

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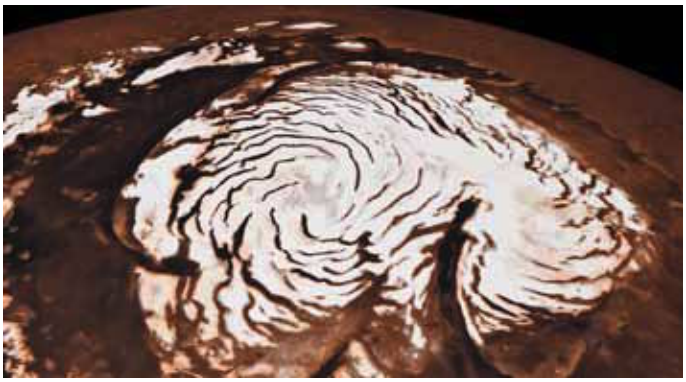
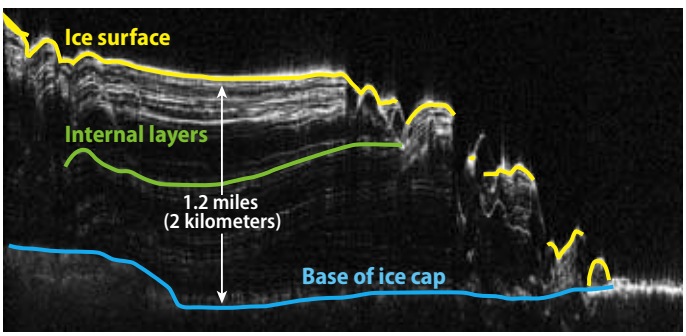


NASA/JPL-Caltech/MSSS

As cold as ice. Mars' north polar ice cap features a large canyon, Chasma Boreale, to the right of center and several spiral-shaped troughs.



NASA/JPL-Caltech/ASI/UT

Layer cake. Radar reveals the internal structure of Mars' north polar cap. White lines show where ice reflected the radar signal back to the Mars Reconnaissance Orbiter spacecraft. The layers' thickness, tilt, and where they bulge tell scientists what the ice sheet's surface was like in the past.

Winds sculpt Mars' north polar cap

Planetary scientists have solved a 4-decade-old mystery about features on the north polar cap of Mars. Researchers used the Shallow Radar (SHARAD) instrument on NASA's Mars Reconnaissance Orbiter to peer beneath the frozen ice cap and view the subsurface geology. The scientists then reconstructed how strong winds helped form a large chasm and an enigmatic series of spiral troughs.

Mars' north polar cap is a stack of ice and dust layers up to 2 miles (3 kilometers) thick and covering an area slightly larger than Texas. One of its most distinctive features is Chasma Boreale, a canyon as long as Earth's Grand Canyon but wider and deeper. Some scientists thought strong winds carved the canyon, while others proposed that volcanic heat melted the ice sheet's base and triggered a flood that created the canyon.

The troughs spiral outward from their centers like giant pinwheels. Theorists suggested winds, solar heating, and even ice cracking under the stress of Mars' rotation as potential causes.

But the new SHARAD observations show that strong winds primarily created and shaped both the canyon and troughs. The process took millions of years as the ice sheet slowly grew. The scientists reported their findings in a pair of papers in the May 27 issue of *Nature*. — **RICHARD TALCOTT**

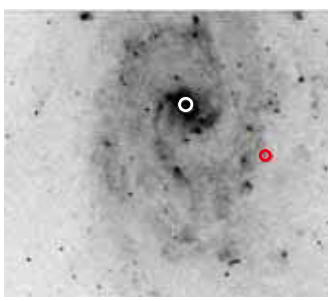
20 Origin of some Milky Way gas clouds discovered

20 Japan on track for Venus

21 Exoplanets orbit star at various angles

21 Volcanic ash coats martian crater

22 New techniques to understand the Sun



Fire away. This nondescript spiral galaxy apparently harbors a supermassive black hole (red circle) located some 10,000 light-years from the galaxy's center (white circle). NASA/STScI

Don't hang around here no more

Astronomers typically find supermassive black holes at the centers of galaxies. But a research team has turned up what appears to be a 1-billion-solar-mass black hole far from a galaxy's center on an escape trajectory from its host.

Marianne Heida of the University of Utrecht in the Netherlands hunted giant black holes by looking for strong X-ray sources near known galaxy positions. Friction heats matter falling into black holes, making them strong X-ray emitters. In one galaxy, Heida discovered such a source some 10,000 light-years from the center.

The team then found an optical counterpart in Hubble images. The research will appear in a future issue of *Monthly Notices of the Royal Astronomical Society*.

The scientists think the object is a black hole created when two smaller black holes collided. The interaction could have shot the new, larger beast out of the galaxy's center at high speed. — **R. T.**

Exoplanets' weird orbits force new look at habitability

Nosy neighbor. Giant exoplanets, such as the one in this illustration, may impact the orbits of any earthlike planets in the vicinity, leading to a redefinition of what scientists consider "habitable." NASA/ESA/G. Bacon (STScI)

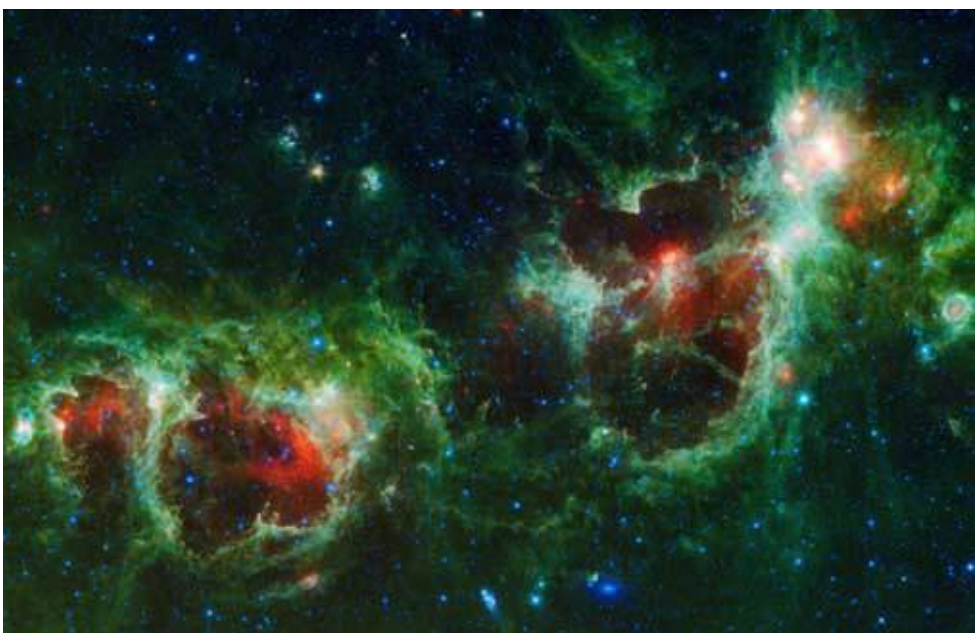
As astronomers hunt for exoplanets, they're particularly searching for an earthlike planet within its star's "habitable zone," the orbital distance that allows for liquid water. Unfortunately, new computer models indicate that it might not be as easy as that.

"The habitable zone is very complicated," says Rory Barnes of the University of Washington, who presented the findings May 24 at a meeting of the American Astronomical Society in Miami, Florida. "It is possible that in many exoplanetary systems the layout of the planets is very important to habitability."

An unusual orbit could mean a planet is only sometimes habitable, with liquid water on its surface. "For part of the time, liquid water could exist on the surface, but at others it would boil off," Barnes says. And all it would take is a Jupiter-sized planet orbiting in a highly elliptical orbit (a description that fits many exoplanets) to sufficiently perturb an earthlike planet's orbit.

Such a perturbed orbit might mean the planet experiences occasional epochs of freezing or boiling temperatures in between ideal habitable eras. Even the length of a day could vary wildly, which would almost certainly have an impact on life and evolution.

"There is this crazy zoo of planets out there that probably are habitable," Barnes says, "but their properties are very different from Earth, and they're different because of their eccentric neighbors." — **BILL ANDREWS**



Falling for the Heart and Soul nebulae

Starry soul. NASA's Wide-field Infrared Survey Explorer (WISE) produced this ethereal image of the Heart and Soul nebulae, two giant clouds of gas about 6,000 light-years away. The Heart Nebula (right) and the Soul Nebula both produce stars at a frantic pace, and WISE's vision allows it to see past cool dust to peer at the budding stars deep inside both nebulae. In this image, blue and cyan indicate light from stars, while green and red indicate light from warm dust. — **B. A.** NASA/JPL-Caltech/UCLA

QUICK TAKES

IN-FLIGHT ASTRONOMY
NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) made its first in-flight night observations May 26.

PLANET'S DAYS NUMBERED
A paper in May 10's *The Astrophysical Journal Letters* confirms that exoplanet WASP-12b may have as few as 10 million years left before its parent star completely destroys it.

MAKING WAVES
Elusive gravitational waves, which could help explain the early cosmos, may be easiest to detect by studying the cosmic microwave background, according to a May 21 *Science* paper.

LARGEST. GALAXY. EVER.
A paper published May 12 in *The Astrophysical Journal Letters* explores the strong gravitational lens in galaxy cluster Abell 3827. Researchers think the lens may be caused by the largest galaxy in the nearby universe.

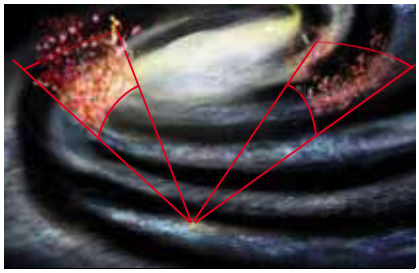
FAINT BLACK HOLE
The Andromeda Galaxy's central supermassive black hole is 10,000 to 100,000 times fainter than expected given its surroundings, Harvard scientists announced May 25 at an American Astronomical Society meeting in Miami, Florida.

PREDICTABLY VIOLENT
British astronomers report in a future issue of *Monthly Notices of the Royal Astronomical Society* that they have observed a pair of white dwarfs with unusually regular violent eruptions of helium.

MARS DEPOSIT
A May 26 *Science Now* paper shows how Mars' largest unexplained feature may have formed due to deposition of materials and not ice flow or erosion.

FIRST MEASUREMENTS OF RARE STAR
A paper published May 28 in *The Astrophysical Journal Letters* announced the discovery of two white dwarfs in an eclipsing binary system, allowing the first direct measurements of a rare pure-helium white dwarf.

GOLDEN OPPORTUNITY
NASA announced May 19 that its Opportunity rover had surpassed the Viking 1 Lander's duration record, making it the longest-running mission on the martian surface.



Location, location. Astronomers found more abundant hydrogen gas clouds where the Milky Way's central bar merges with a spiral arm (at left) compared to another studied region (at right). The yellow dot at the bottom of this illustration is our solar system. Bill Saxton, NRAO/AUI/NSF

Origin of some Milky Way gas clouds discovered

Hydrogen gas clouds seem to prefer certain regions of the Milky Way Galaxy to others, say astronomers. F. Jay Lockman of the National Radio Astronomy Observatory announced his team's findings May 26 at the American Astronomical Society meeting in Miami, Florida.

The astronomers studied about 650 hydrogen gas clouds in two separate regions of the Milky Way using data from the Parkes radio telescope in Australia. In both regions, the clouds lie between 400 and 15,000 light-years outside the galaxy's disk, although not as distant as the Milky Way's surrounding halo. When the team compared observations of the two areas, it found that one holds 3 times as many hydrogen clouds as the other.

The area with more gas clouds is located near where the galaxy's central bar meets with a major spiral arm. This denser region of the Milky Way harbors intense star formation, where winds from young stars blow surrounding gas away. Star formation is sparse in the region with fewer hydrogen clouds.

"The properties of these clouds show clearly that they originated as part of the Milky Way's disk and are a major component of our galaxy," says Lockman. "Understanding these clouds is important in understanding how material moves between the galaxy's disk and its halo, a critical process in the evolution of galaxies." **— LIZ KRUESI**

Japan on track for Venus

Shortly after dawn May 21, the twin solid rocket boosters of an H-IIA launch vehicle roared to life at Japan's Tanegashima Space Center. Not content with conducting a single mission, Japan packed two major spacecraft in the payload bay: Akatsuki will explore Venus' thick atmosphere, and IKAROS will test solar-sail technology.

Akatsuki, Japanese for "dawn," also goes by the name Venus Climate Orbiter. It will arrive at Venus in December, when it will enter a highly elliptical orbit around Earth's "twin." The mission should last at least 4 years.

Although Venus nearly matches Earth in size and composition, the similarity of the two worlds stops there. Venus' atmosphere is about 100 times denser than Earth's and consists mostly of carbon dioxide, with high-altitude clouds of sulfuric acid. Akatsuki's goal is to help scientists understand how the two planets evolved so differently.

To accomplish this task, Akatsuki carries five cameras. The Lightning and Airglow Camera will search for lightning in the visible part of the spectrum; the Longwave Infrared Camera will view high-altitude clouds at a wavelength of 10 micrometers; the Ultraviolet Imager will examine atmospheric gases at wavelengths between 293 and 365 nanometers; the 1-micron camera will observe at wavelengths between 0.9 and 1.01 micrometers and reveal heat from the surface; and the 2-micron camera will operate between 1.65 and 2.32 micrometers, which will record heat from the atmosphere's lower levels.

IKAROS is a tongue-twisting acronym that stands for Interplanetary Kite-craft Accelerated by Radiation Of the Sun. This giant solar sail is a square measuring 66 feet (20 meters) diagonally but only 0.0075 millimeter thick. The sail generates propulsion from the radiation pressure supplied by solar photons. IKAROS gets additional energy from thin solar cells. The Japanese Space Agency (JAXA) says the mission should complete its technology goals in 6 months.

The IKAROS spacecraft will test technology Japan plans to use for future missions. By 2020, JAXA hopes to launch a mission to Jupiter and the Trojan asteroids. This spacecraft would reach its targets by using a solar sail 164 feet (50m) across combined with ion propulsion. **— R. T.**

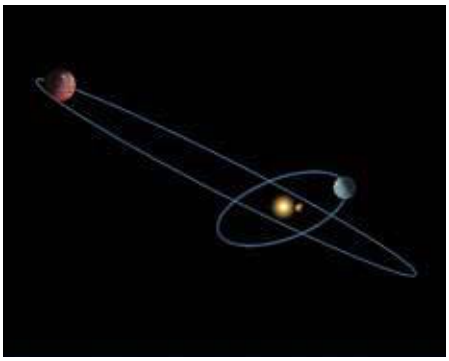
Wild blue yonder. An H-IIA launch vehicle lifts off from Japan's Tanegashima Space Center May 21, carrying one spacecraft on its way to study Venus' atmosphere and another to test a giant solar sail. JAXA

Pale blue crescent. The Akatsuki spacecraft captured this view of Earth through its Ultraviolet Imager from a distance of 155,000 miles (250,000 kilometers) less than 1 day after launch. JAXA

Not the Red Planet. Akatsuki's 1-micron camera snapped this infrared image of Earth from 155,000 miles (250,000 kilometers) during tests of the spacecraft's instruments. JAXA

Stellar castaway

Hubble discovered a massive star speeding away from its native Tarantula Nebula, likely kicked out by interactions with even bigger stars. The research appeared online May 5 in *The Astrophysical Journal Letters*.



Off-kilter orbits. **This artist's rendering depicts the system of planets surrounding Upsilon Andromedae A, where astronomers recently discovered that the three Jupiter-type planets orbit their star in separate planes, unlike our solar system.** NASA/ESA/A. Feild (STScI)

Exoplanets orbit star at various angles

The more scientists learn about exoplanets, the stranger the distant worlds become. So far, every planetary system discovered, including our own, had the majority of planets orbiting their star in the same plane; the systems were nearly flat. But, as Barbara McArthur of the University of Texas at Austin explained May 24 at a meeting of the American Astronomical Society in Miami, Florida, this is no longer the case.

The three known Jupiter-type planets around the dwarf star Upsilon Andromedae A, which lies about 44 light-years away, have turned out to orbit at steep angles to one another. Such an "out of whack" system means "astronomers can no longer assume all planets orbit their parent star in a single plane," says McArthur. Her team used the Hubble Space Telescope and other telescope data along with extensive modeling to determine the nature of these orbits.

Previously, astronomers assumed planetary systems started out as gigantic clouds of gas that collapse down into stars and planets, leaving a disk behind that gradually coalesces into a solar system-like arrangement.

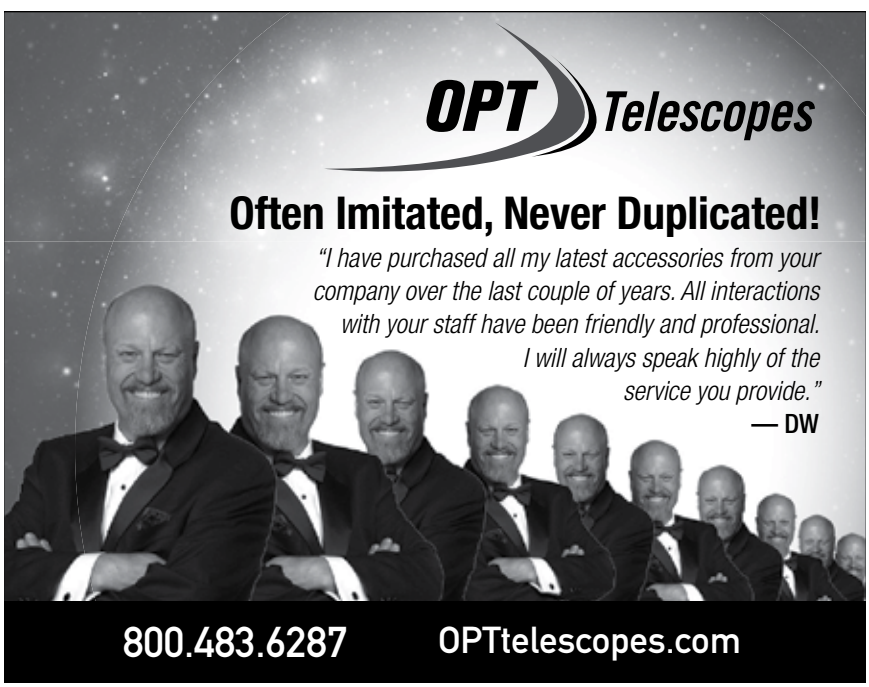
Just why Upsilon Andromedae's planets are different remains up for debate. "Possibilities include interactions occurring from the inward migration of planets, the ejection of other planets from the system through planet-planet scattering, or disruption from the parent star's binary companion star, Upsilon Andromedae B," McArthur says.

One thing is clear, though. As McArthur says, when it comes to exoplanets, "we're not in Kansas anymore." — **B. A.**

ESA/DLR/FU Berlin (G. Neukum)

Volcanic ash coats martian crater

Dark as night. **Deposits of volcanic ash color this part of Meridiani Planum, a large plain located near Mars' equator. The dark material covers most of the floor of the 30-mile-wide (50 kilometers) impact crater at the center of this image. Prevailing northeasterly winds have blown some of these ash-rich sediments out of the big crater and across the surrounding terrain. The European Space Agency, whose Mars Express spacecraft captured this scene, released the image May 12. — R. T.**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Blank solar slate. As this recent image shows, sunspot activity remains weak, making the current solar minimum unusually long.

New techniques to understand the Sun

Astronomers discussed three new techniques to study the Sun, and potentially predict future behavior, May 26 at the American Astronomical Society meeting in Miami, Florida. "Jet streams," rhythmic oscillations, and magnetic activity all provide avenues to study solar activity. Typically, the Sun has an 11-year cycle, during which the number of sunspots rises to a maximum and then falls to a minimum.

David H. Hathaway of NASA's Marshall Space Flight Center used meridional flow (a sort of solar jet stream), which he found has historically correlated with solar cycle intensity. He predicts that the Sun's current cycle (Cycle 24) should peak in 2013, though it likely will be only about half the size of the past three solar maxima.

Sushanta Tripathy and Frank Hill of the National Solar Observatory studied vibrations from the Sun's surface called rhythmic oscillations. They found a strong correlation between these oscillations and solar activity and used it to show there was a "double minimum" in seismic activity that likely accounts for the unusually long present minimum.

Finally, Julia Saba of NASA's Goddard Space Flight Center analyzed the Sun's magnetic field activity, allowing her to predict 18 months in advance when Cycle 24 would begin and to speculate that Cycle 24 will be weaker and longer than average. — **B. A.**

Taking a fresh look

Perfect pinwheel. About 15 million light-years away in Hydra, the Southern Pinwheel Galaxy (M83) shines bright enough to see through binoculars. The European Southern Observatory (ESO) released this new image May 19 showing the galaxy in unprecedented detail for a ground telescope. ESO's Very Large Telescope in Chile snapped this picture using infrared light, showing off the galaxy's star clusters in exquisite detail. — **B. A.** ESO/M. Gieles

BRIEFCASE

Most distant cluster spotted

Astronomers using the Subaru optical-infrared telescope and XMM-Newton X-ray satellite have broken the record for the most distant galaxy cluster discovered. In fact, they found two clusters close to each other, both corresponding to distances of 9.6 billion light-years away. The previous record-holder was some 9.2 billion light-years distant. — **L. K.**

Phoenix fails to rise

NASA declared in May that its Phoenix Mars Lander had succumbed to martian winter. Phoenix last communicated with Earth in late 2008, but NASA did not give up all hope until May's attempt failed. Images from the Mars Reconnaissance Orbiter's HiRISE camera confirmed Phoenix's ill health. "The latest image appears to show that a solar panel on the lander has collapsed," says HiRISE principal investigator Alfred McEwen of the University of Arizona. Scientists think hundreds of pounds of frost built up on the panels during the winter. — **R. T.**

The shape of things to come

Scientists at University College London and the University of Cambridge have developed a computer algorithm to classify galaxies accurately and efficiently. The new method agrees with human classifications of galaxies more than 90 percent of the time. The researchers used results from the ongoing Galaxy Zoo project (see "Welcome to the Galaxy Zoo," page 30) to train the computer. — **R. T.**

25 years ago in *Astronomy*

September 1985

In the September 1985 issue, astroimager Robert Reeves described how to make "A Portable Astrophotography Platform for Travelers." With the imminent return of Halley's Comet to the inner solar system, the "event we've all been waiting for," many photographers facing the long trip to the Southern Hemisphere had to decide between leaving their normal celestial photo rigs behind or bringing them and paying huge airline fees for the extra weight.

With detailed pictures and a step-by-step approach, Reeves provided the plans to make a portable platform with "all the essentials for fully-guided astrophotos," useful for any future trips. "Best of all," Reeves wrote, when your friends brag about their great exposures, "you can haul out your equally good shot taken with the guider you made for less than the price of a high-grade eyepiece!"

September 2000

10 years ago in *Astronomy*

In the September 2000 issue, astronomer James B. Kaler explained the nature of light and its astronomical value as he took readers "Beyond the Rainbow."

Kaler first dove into the various forms of electromagnetic radiation (radio waves, infrared, visible light, X-rays, etc.), detailing how they differ, exploring our history discovering and manipulating them, and offering a basic primer about their dual particle/wave nature. He then took readers to the stars, showing how astronomers can use infrared and gamma-ray instruments to probe deeper than ever before.

"Our century," he wrote, speaking of the 20th, "has seen the entire electromagnetic spectrum opened for business. With new detectors … astronomical objects will yield up their various secrets at an ever-accelerating pace, allowing a fuller understanding of our universe." — **B. A.**

Ambling black hole A team of scientists at the May 25 meeting of the American Astronomical Society in Miami announced that the supermassive black hole in nearby galaxy M87 isn't centered, suggesting it migrated from its original location.

And then there were three

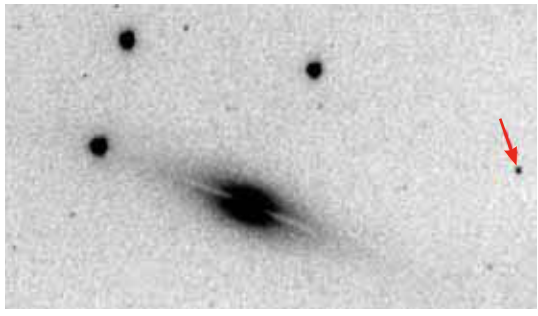
How many ways can a star blow up? For decades, astronomers thought nature had found two paths to creating supernovae, the stellar explosions that can shine as bright as entire galaxies. In one, a massive star's core collapses at the end of its life, creating a shock wave that expels all of the star's outer layers. In the other, a white dwarf star accretes matter from a binary companion until it reaches 1.4 solar masses. The white dwarf can't support any more weight and detonates in a titanic thermonuclear explosion.

But a team of astronomers now argues that SN 2005E — a supernova that lit up the spiral galaxy NGC 1032 in 2005 — represents a third way. The team's analysis shows that the explosion occurred in a region devoid of massive stars, ejected a paltry amount of material (0.3 solar mass), and created abnormally high levels of calcium and radioactive titanium.

The team concludes that the supernova took place in a low-mass white dwarf that stole helium from a companion star. "We know that SN 2005E came from the explosion of an old, low-mass star because of its location in the outskirts of a galaxy devoid of recent star formation," says team member Alex Filippenko of the University of California, Berkeley. "And the presence of so much calcium in the ejected gases tells us that helium must have exploded in a thermonuclear runaway."

The researchers, who were led by Hagai Perets of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, and Avishay Gal-Yam of the Weizmann Institute of Science in Rehovot, Israel, calculate that calcium made up about half of the ejected mass. A galaxy would need only a couple of such supernovae per century to produce the amount of calcium observed in the Milky Way and incorporated into life on Earth. The team reported its findings in the May 20 issue of *Nature*. — **R. T.**

Spiral showcase. The edge-on spiral NGC 1032 hosted the calcium-rich supernova SN 2005E. SDSS/Lick Observatory



Strange blast. Supernova 2005E (arrow) occurred in NGC 1032's halo, a region far from any star formation. Astronomers think the blast originated from a low-mass white dwarf that was accreting helium. SDSS/Lick Observatory

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The next great space

Phil Sabelhaus hasn't slept well for a week. The project manager for the James Webb Space Telescope paces the hallways of the European Space Agency's launch center near Kourou, French Guiana. In the distance, an Ariane 5 ECA rocket awaits the signal that will bring its engines roaring to life. Its payload is nothing less than the largest space observatory ever built. Just folding the tennis-court-sized craft to fit it into the payload shroud seems more origami than engineering. But Webb's mission is as simple as its design is state of the art: to show us what Hubble cannot.

Although this scene lies a few years in the future, the reality of the Webb telescope is becoming harder to miss at three NASA centers. Last year, technicians removed lamps designed to simulate the Sun — lamps that had been in place since the Apollo program — from the enormous thermal-vacuum test chamber at Johnson Space Center in Houston, Texas. In January, engineers at Marshall Space Flight Center in Huntsville, Alabama, began testing six of Webb's primary-mirror segments.

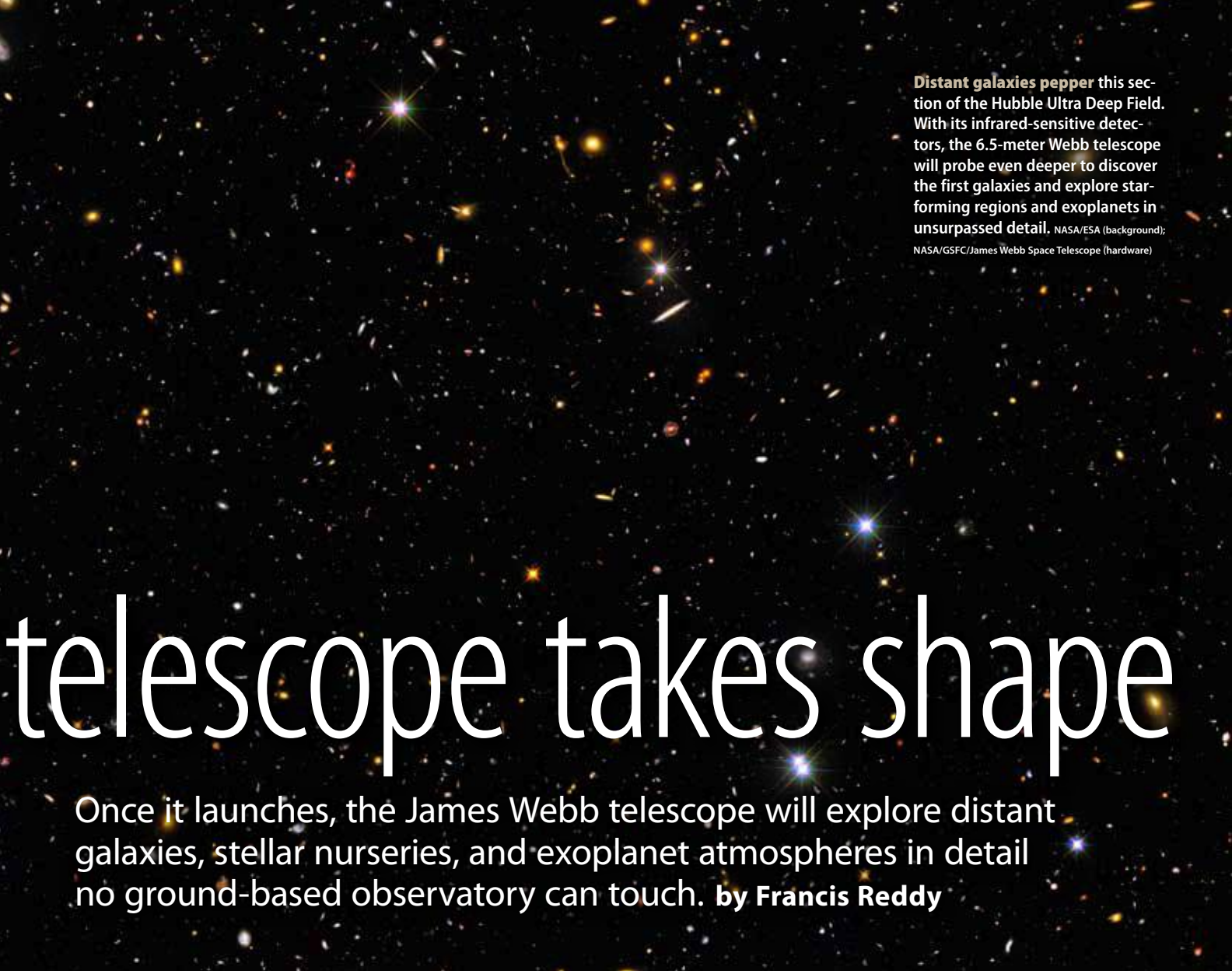
And at Goddard Space Flight Center in Greenbelt, Maryland, which leads both the Webb and the Hubble Space Telescope projects, the large clean room passed a significant milestone in March: "For the first time in 20 years, there is no trace of Hubble-related testing and support equipment," says Goddard's Sabelhaus. "We've pulled it all out."

By year's end, NASA will be putting the finishing touches on the Webb telescope's 18 mirror segments, and all flight instruments will be nearing completion. "There's an awful lot of work to do, but the majority of the mass of the observatory already exists," says Goddard's Jonathan Gardner, the deputy senior scientist for Webb.

Francis Reddy *is the senior science writer for the Astrophysics Science Division at NASA's Goddard Space Flight Center in Greenbelt, Maryland.*

From Mount Wilson to Webb

For ground-based observatories, a similar transition from Hubble- to Webb-sized mirrors spanned nearly 60 years, from the famous 100-inch (2.5 meters) telescope



Distant galaxies pepper this section of the Hubble Ultra Deep Field. With its infrared-sensitive detectors, the 6.5-meter Webb telescope will probe even deeper to discover the first galaxies and explore star-forming regions and exoplanets in unsurpassed detail. NASA/ESA (background); NASA/GSFC/James Webb Space Telescope (hardware)

telescope takes shape

Once it launches, the James Webb telescope will explore distant galaxies, stellar nurseries, and exoplanet atmospheres in detail no ground-based observatory can touch. **by Francis Reddy**

on Mount Wilson in California, which Edwin Hubble used in the 1920s to show that the universe is expanding, to the Soviet Union's 6-meter (238 inches) Bolshoi Azimuthal Telescope in 1975. If all goes according to plan, the Webb project will accomplish the same mirror growth in space in just 40 percent of the time.

Webb is an international collaboration among NASA and the European and Canadian space agencies. The partners designed the observatory to tackle a range of astronomical problems. Unlike Hubble, Webb's mission requires it to orbit Earth-Sun L2, the second Lagrange point of the Earth-Sun system and one of five spots where the gravitational pull of the Sun equals that of Earth. L2 lies some 940,000 miles (1.51 million kilometers) from Earth in the direction opposite the Sun.

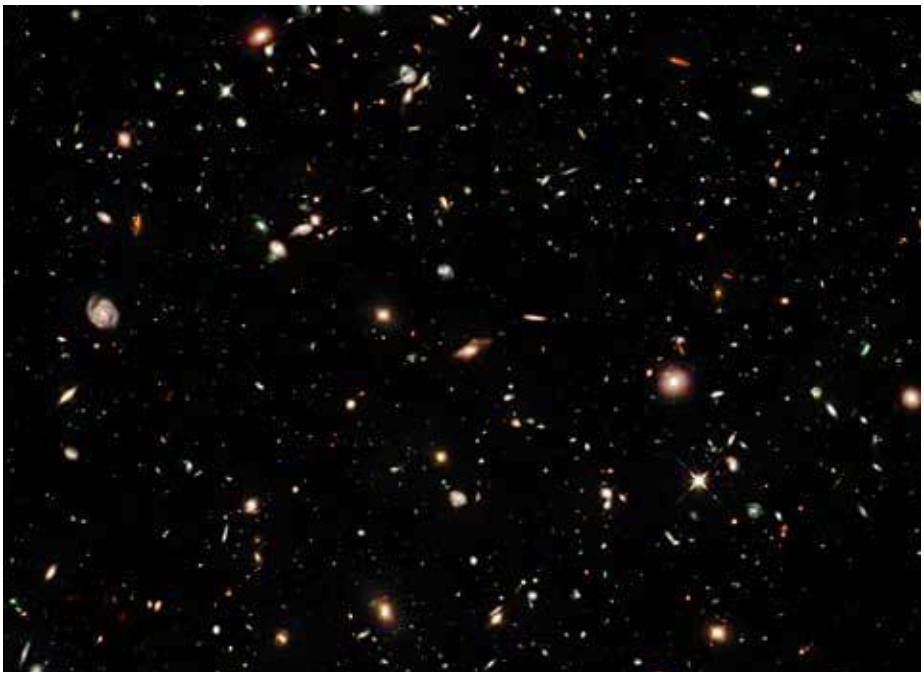
At this location, servicing by astronauts is out of the question: Webb simply must work. To that end, the partners have developed new technologies and a testing program to ensure that every component, assembly, instrument, and structure operates correctly in the extreme environment of space.

No one on the team has forgotten the problem plaguing Hubble's primary mirror, which wasn't resolved until astronauts gave the orbiting telescope the equivalent of contact lenses. So, NASA plans to test Webb's entire optical train — from the primary mirror to all the instruments — as a single unit in a vacuum and at its operating temperature. That's why technicians pulled out the solar simulator from Johnson Space Center's big test chamber.

"We have a lot of people working with us who worked on Hubble, and our test program takes advantage of the mistakes that were made," says Sabelhaus. "We don't depend on just one set of testing to say that the mirror's OK."

When fully deployed, Webb's 18 hexagonal, gold-coated mirror segments will form a primary mirror with an effective diameter of nearly 6.6 meters (259 inches). This gives the telescope more than 6 times Hubble's light-collecting area. Actuators behind the mirror segments, driven by software that analyzes the incoming image, will allow engineers to fine-tune the mirror's overall shape.

Far from any heat sources, and with a sunshield the size of a tennis court providing permanent shade, Webb's telescope and instruments will cool passively



In near-infrared light, Hubble's Ultra Deep Field reveals galaxies as they appeared just 600 million years after the Big Bang. With its infrared capabilities, Webb should find galaxies within 200 million years of the universe's birth. NASA/ESA/G. Illingworth and R. Bouwens (UC-Santa Cruz)/The HUDF09 Team

to their operating temperature of –388° Fahrenheit (–233° Celsius). About 6 months after it arrives at L2, the observatory will begin its 5-year — or with luck, decade-long — science mission.

Seeing red

Astronomers began discussing a successor to Hubble in 1989, a full year before it even reached orbit. By the mid-1990s, they had narrowed the specifications to a space telescope with a 4-meter or larger mirror optimized for the infrared, the part of the spectrum just beyond visible light.

Why infrared? Hubble has provided tantalizing looks at the youngest galaxies astronomers have ever seen, but there is a limit to how far back in time it can see. Not only are these distant sources small and faint, but cosmic expansion also stretches and reddens their light as it travels to us. And the farther away a galaxy lies, the greater its redshift.

For example, a galaxy at redshift 1 (whose light has shifted by 100 percent) lies nearly 8 billion light-years away, and we see it as it looked when the universe was slightly less than half its present 13.7-billion-year age. In this sense, looking farther into the universe is akin to time travel. As mind-blowing as these numbers are, however, we can reduce them to human terms. Looking from the present-day cosmos to a galaxy at redshift 1 is equivalent to a 70-year-old woman seeing herself as a 30-year-old.

Astronomers have a trick they use to quickly estimate redshifts. Ultraviolet light at a wavelength of 91 nanometers packs enough energy to strip electrons from hydrogen atoms. As a result, hydrogen scattered throughout the cosmos absorbs radiation at this and shorter wavelengths. So, by viewing a distant galaxy through filters tuned to different wavelengths, astronomers can estimate its distance by looking for the wavelength where the galaxy disappears.

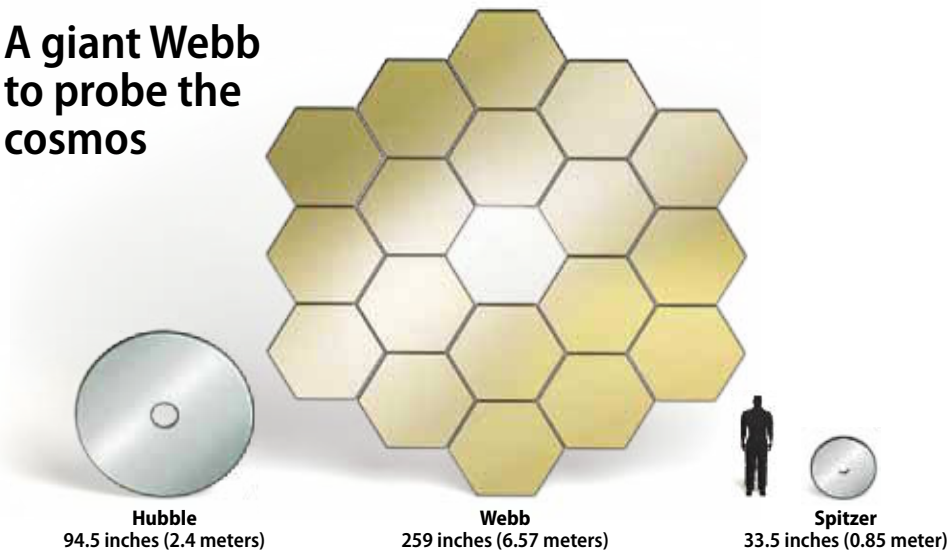
Near redshift 3.5, the expansion of space pulls this galactic-dropout feature out of the ultraviolet and into the visible spectrum. At this distance, light from Sun-like stars has already shifted to infrared wavelengths. By redshift 7.5, the dropout feature itself lies in the infrared.

Looking deep into the infrared also helps Webb stand apart from the large ground-based facilities astronomers expect to build in the next decade. "We're planning to do science they could never touch," says Goddard's John Mather, the chief scientist for Webb. That begins at a wavelength around 1.7 microns, where ground-based telescopes and even Hubble start to emit radiation.

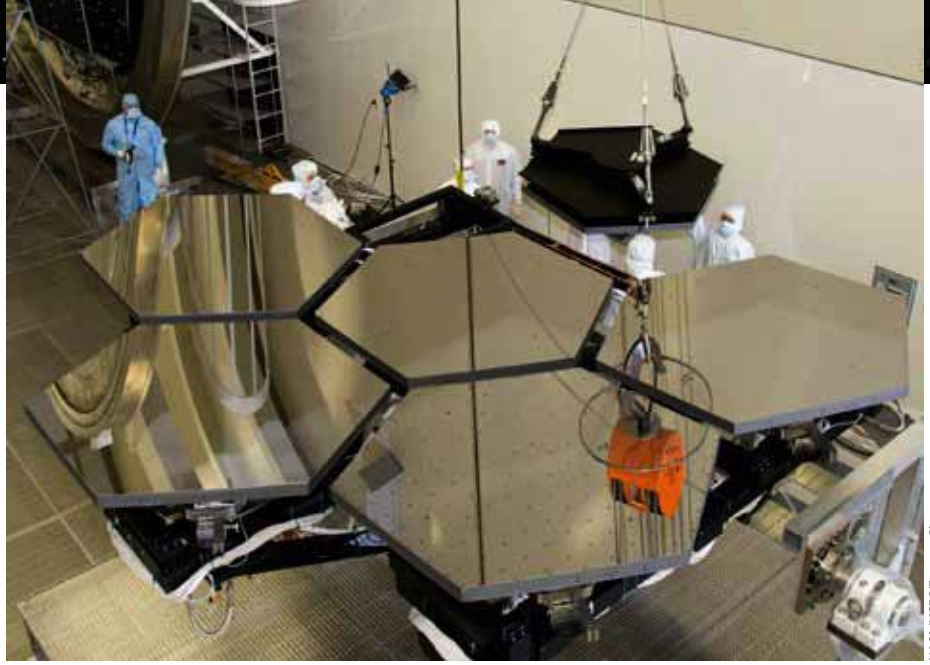
"Even the atmosphere glows, and it quickly becomes opaque at most infrared wavelengths with a few special exceptions," Mather explains. "By the time you're out to 5 microns, Webb is roughly a million times better than a ground telescope of the same size. That's huge." Webb's mid-infrared instrument further presses this advantage, giving the telescope a sensitivity out to 28.5 microns.

Galaxy quest

Since 2002, when astronauts installed Hubble's Advanced Camera for Surveys,



Webb dwarfs the Hubble Space Telescope. Webb has more than 6 times the light-gathering power of Hubble, so it can view fainter objects and record all objects in less time. Webb will collect more than 50 times the light of NASA's current infrared telescope, Spitzer. *Astronomy*: Roen Kelly



NASA/MSFC/Emmett Givens

Six mirror segments undergo preparations before moving into Marshall Space Flight Center's X-ray and Cryogenic Facility, where they will experience temperatures down to –414° F (–248° C).

A technician examines a mirror segment at Tinsley Laboratories in Richmond, California. Tinsley grinds and polishes the mirrors to NASA's exact specifications. SSG/Tinsley

astronomers have used it and the dropout technique to measure the distances of some 6,000 galaxies between redshifts 3 and 6. In 2005, spectral measurements confirmed that a single dropout galaxy captured in the Hubble Ultra Deep Field (HUDF) — the telescope's 11-day-long "stare" at a relatively empty spot in the southern sky — lies at redshift 6.7, corresponding to a cosmic age of just 800 million years. Continuing our human analogy, that's equivalent to a 70-year-old seeing herself as a 4-year-old.

This comparison is more apt than you might think because nearby galaxies bear little resemblance to those far away. In the 1920s, Edwin Hubble's galaxy studies revealed that roughly half of nearby galaxies are spirals similar to our Milky Way. The remainder are ellipticals (40 percent) and irregular galaxies or galaxies caught in the act of merging (10 percent).

According to surveys made with the Hubble Space Telescope in the 1990s, the accounting becomes topsy-turvy by redshift 1. At this distance, the cosmos contains fewer than half as many spiral and elliptical galaxies and more than 5 times the number of irregulars and mergers seen in our neighborhood. Many of the farthest galaxies Hubble sees are small, faint, and distorted, underscoring the idea that dwarf galaxies, roughed up by numerous rounds of collisions, produced the universe we see today.

Last year, a team led by Garth Illingworth at the University of California, Santa Cruz, used Hubble's new Wide Field Camera 3 to push the "red limit" even farther back (see "Galaxies near the dawn of time," May 2010). These researchers found dropout galaxies between redshifts 7 and 8 in the HUDF. Since then, they have seen hints of a few galaxies at redshifts possibly as high as 10. If confirmed, we're seeing these galaxies less than 500 million years after the universe was born.

James Webb's "backplane" serves as the telescope's spine, holding and supporting the mirror segments and some 7,500 pounds (3,400 kilograms) of optics and science instruments. This simulator at Northrop Grumman in Redondo Beach, California, will make sure the telescope's actual components will fit properly. Northrop Grumman

That confirmation will come from the James Webb Space Telescope, which will probe the early universe to redshift 20 or more — within 180 million years of the Big Bang. At these distances, the universe itself will be comparable, in human terms, to our 70-year-old woman seeing herself as an 11-month-old toddler. But any dwarf galaxies Webb finds out there will be newborns.

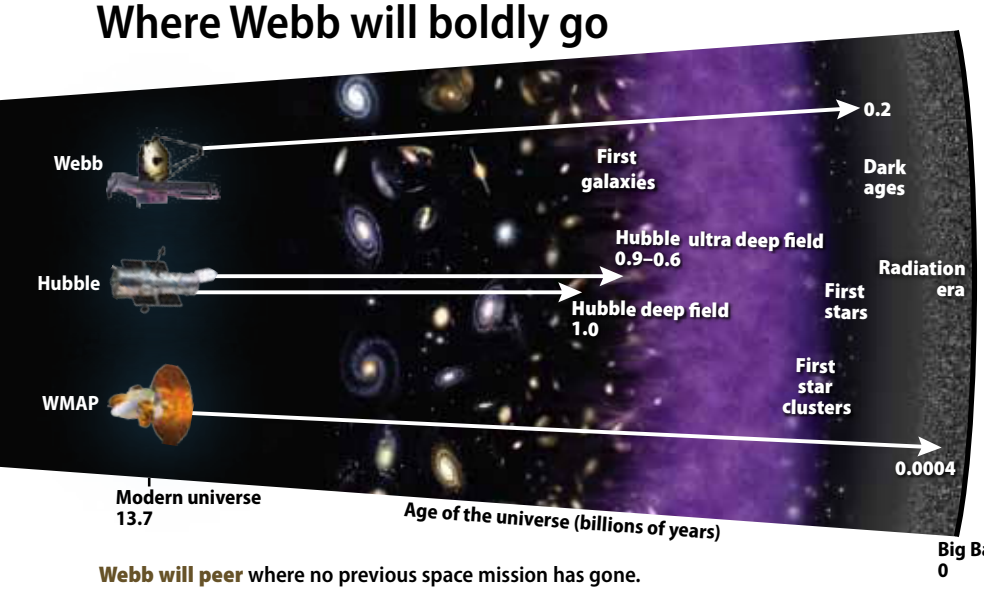
Another Webb innovation, called microshutters, gives the observatory the ability to capture spectra of hundreds of galaxies at a time. Inside the telescope's Near-Infrared Spectrograph, four postage-stamp-sized arrays contain nearly a quarter of a million micro-electromechanical shutters, each of which can be opened and closed magnetically.

"With thousands of galaxy spectra in hand, we'll be able to view changes in their chemical evolution by redshift or by galaxy type," says Gardner. "Webb will answer a lot of questions about how galaxies came to be."

Superstars

Webb also will probe exploding stars in distant galaxies. These supernovae shine so brightly that astronomers can see them over immense distances. They serve as powerful probes of dark energy, the mysterious force that seems to be accelerating cosmic expansion. "We have the sensitivity to see individual supernovae to redshift 15 and more, but they're probably pretty rare and it will be hard

Where Webb will boldly go



Webb will peer where no previous space mission has gone. Hubble's Ultra Deep Field looked at galaxies within a billion years of the Big Bang, and the Wilkinson Microwave Anisotropy Probe (WMAP) views the cosmic background radiation from 380,000 years after cosmic genesis. Only Webb can look between, perhaps to the first stars and galaxies. *Astronomy*: Roen Kelly

to find one," says Mather. He suggests that large ground-based facilities now under construction might help project scientists find suitable targets.

Another consequence of cosmic expansion is that we see the high-redshift universe in slow motion. For example, a nearby supernova typically takes a few days to reach peak brightness and a few months to fade away. But a supernova seen at redshift 10 would take a month to reach peak brightness and years to fade. "To see them, you need a pretty long-lived mission and you have to be patient," Mather notes.

Astronomers believe the first stars possessed at least 100 times the Sun's mass, shone millions of times brighter than our star, and lived only a few million years before exploding as supernovae. Although Webb might catch one of these rare explosions, the telescope has enough sensitivity to locate aggregations of the stars themselves. "Did the first stars even form star clusters? Or did the first in a region poison the mix for the rest, preventing star formation nearby? We don't know," says Mather.

Recently, Katherine Freese at the University of Michigan in Ann Arbor led a study that suggests a novel type of star may be within Webb's reach. These stars would consist largely of dark matter, the mysterious stuff that seems to make up the majority of the universe's mass.

Some of the theories that explain dark matter as a hitherto unknown subatomic particle also suggest that collisions between two such particles would annihilate them, releasing lots of energy. Douglas Spolyar at Fermilab in Batavia, Illinois, has shown that this mutual annihilation of dark matter particles could provide the energy source for a new stage of stellar evolution.

Freese and her colleagues calculate that these "dark stars" would have masses between 100,000 and 10 million Suns and sizes up to 100 times the Sun-Earth distance. Once collisions exhaust the central dark matter, the stars would transform into massive normal stars burning nuclear fuel. These eventually would collapse into black holes — perhaps forming seeds for the supermassive black holes now found

Webb's sunshield, which will match the size of a tennis court once it unfurls in space, will protect the telescope from the Sun's light and heat. Engineers put this sunshield model through folding and deployment tests in 2006 and 2007. Northrop Grumman

The man behind the name

James Webb NASA

In 2002, NASA named its newest space telescope to honor James Edwin Webb (1906–1992). From 1961 to 1968, Webb served as the space agency's second administrator. Although he presided over the manned space program that led to the first lunar landing in 1969, Webb stressed from the outset the need for a balanced science program. Under his tenure, NASA launched its first probes to Venus and Mars, solar observatories, and satellites dedicated to understanding the universe beyond our solar system. — *F. R.*

A hotbed of star formation, this 3-light-year-tall pillar in the Carina Nebula looks dramatically different when viewed by Hubble through visible light (left), which emphasizes dark dust and glowing gas, and near-infrared light (right), which reveals the stars inside. Webb's infrared vision will probe even deeper into such star-forming regions and with far higher resolution. NASA/ESA/M. Livio and the Hubble 20th Anniversary Team (STScI)

at the heart of every large galaxy. "This is a remarkable prediction, and I think it would be cool if dark matter stars turn out to be working out there," says Mather.

Inside the cocoon

Closer to home, Webb's infrared sensitivity will enable the telescope to probe the dusty sites where stars and planets form. "All of the action in a star-forming region like the Orion Nebula is happening behind dust clouds," says Gardner. "They make a pretty picture but hide what's going on inside." Hubble already has resolved dusty circumstellar disks that may eventually form planets, but Webb's infrared capability and higher resolution will penetrate these cocoons and allow astronomers to see what's going on inside.

All of Webb's imaging instruments include coronagraphs, devices that can block the light from a central star to view faint objects near it. In 2004, Hubble used this technique to produce the first-ever visible-light image that resolved the region around the bright star Fomalhaut. The image shows an off-center dust ring surrounding the star. Paul Kalas at the University of California, Berkeley, Goddard's Mark Clampin, and their colleagues suggested that a planet lying between the star and the ring's inner edge was gravitationally modifying the ring. They used this offset to predict the planet's location. In 2008, the team used Hubble to directly image the planet, Fomalhaut b.

Dusty protoplanetary disks surround many of the stars forming in the Orion Nebula. Astronomers think planetary systems eventually will develop from such disks. The disks appear either bright or dark depending on their distance from the hot stars at the nebula's core. Although Hubble imaged these disks, Webb's infrared eyes will penetrate these dusty cocoons. NASA/ESA/L. Ricci (ESO)

Webb may be able to see structure in Fomalhaut's disk as small as 10 times the Sun-Earth distance (about the size of Saturn's orbit), which could indicate the presence of additional planets. It will do the same for other nearby disk systems, like the one surrounding Vega.

Both the Hubble and Spitzer space telescopes have begun to characterize the atmospheres of transiting "hot Jupiters," close-in gas-giant exoplanets that pass in front of their stars as seen from Earth. "Webb will take us to smaller planets — super-Earths with perhaps a few times Earth's mass that orbit cool red dwarfs," says Gardner. Between direct imaging using coronagraphs and atmospheric measurements made through transit observations, Webb will be a powerful tool for surveying the exoplanet zoo and learning how planetary systems form.

These represent only a few of the scientific questions that the James Webb Space Telescope will address. A year before launch — now planned for late 2014 or early 2015 — astronomers around the world will start proposing targets and observing plans. In the same way Hubble operates, a scientific panel will rank these proposals and select the best to receive time on the telescope. "We expect that people will come up with clever new ways of using it, and the universe will surprise us with discoveries we can't predict," says Gardner.

Asked to anticipate Webb's launch, Sabelhaus is pretty sure he won't sleep well the nights before liftoff. "You question every decision you've made, and you make sure you have procedures in place for every conceivable contingency," he says.

But when Mather and Gardner look forward to launch day, they quickly leap to the thrill of the science Webb promises to deliver. With dark stars, strange worlds, and newborn galaxies as appetizers, who wouldn't anticipate the menu.

To see an animation of Webb's deployment, visit www.Astronomy.com/toc.

Welcome to the GALAXY ZOO

Ordinary people classifying galaxies makes one of the world's most enjoyable citizen science projects also one of the most successful. **by William Keel**

Two astronomers walk into a pub …

This could set up any number of jokes, but in fact it describes the genesis of the Galaxy Zoo project, a uniquely successful research partnership that has grown to involve over a quarter-million people from all walks of life, all over the world, at the forefront of scientific discoveries.

This sample classification screen from the original Galaxy Zoo project shows off the simple, clean layout. The buttons easily allow users to classify any galaxy as clockwise spiral, anti- or counterclockwise spiral, edge-on spiral, elliptical, merging, or "don't know." Galaxy Zoo

One evening in early 2007, two Oxford University astronomers wandered into The Royal Oak pub to unwind a bit, a few blocks from the astrophysics lab and within sight of the 18th-century Radcliffe Observatory tower. Graduate student Kevin Schawinski and postdoctoral researcher Chris Lintott were pondering ways to go beyond the scope of Schawinski's dissertation project. Somehow, he had to visually sort through 50,000 galaxies from the Sloan Digital Sky Survey (SDSS) to identify samples of interest. (Incidentally, Lintott is perhaps better known as co-presenter of the long-running BBC television production *The Sky at Night*, along with Patrick Moore.)

Inspired by the success of such projects as NASA's Stardust@Home, which invited the public to help find interstellar dust grains captured by the Stardust mission, they soon found that some local cosmologists had thought of a similar way to improve our knowledge of other issues such as the similarity of galaxy spins. Lintott and Schawinski envisioned a system in which members of the public could help classify all of the nearly one million galaxies in the SDSS main galaxy sample — if not in full detail, certainly into broad categories that would be useful for a range of scientific problems. They sketched the first draft of the interface and system design on a napkin. With that, Galaxy Zoo was born.

University of Alabama astronomer **William Keel** *specializes in the study of galaxies, specifically their history, interactions, and content. He is author of* The Road to Galaxy Formation *(Springer Praxis, 2002) and* The Sky at Einstein's Feet *(Springer Praxis, 2005).*

The Royal Oak pub at Oxford is the site of the Galaxy Zoo's genesis. After astronomers Kevin Schawinski and Chris Lintott came up with the idea over drinks, they sketched the first details on a cocktail napkin. William Keel

They sketched the first draft of the interface and system design on a napkin. With that, Galaxy Zoo was born.

Alvin555 | Dreamstime.com, *Astronomy*: Alison Mackey

As these images demonstrate, the general galaxy classifications of counterclockwise spiral, clockwise spiral, edge-on spiral, elliptical, and merging are relatively easy to distinguish. (From top left to bottom right: M51, M83, NGC 4710, NGC 1132, and NGC 6670.) Most galaxies, however, don't fit so cleanly into these categories. NASA/ESA/S. Beckwith (STScI)/The Hubble Heritage Team (STScI/AURA); European Southern Observatory; NASA/ESA/P. Goudfrooij (STScI); NASA/ESA/Hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration; NASA/ESA/Hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration/A. Evans (University of Virginia, Charlottesville/NRAO/Stony Brook University)

Birth pains

Fortunate timing led to a quick boost from news stories on the BBC's website. So many users tried to sign up and take part that it damaged the computer originally serving the data. The quick work of a team at Johns Hopkins University in Baltimore saved the day, and probably the project; Galaxy Zoo thus learned to be ready to respond quickly when public interest is high.

Galaxy Zoo began modestly enough as a way to expand the number of galaxies a single graduate student could examine. It not only has yielded a series of hitherto-unavailable science results, however, but it also became a pathfinder for participatory citizen science in the Internet age. In this it goes beyond projects such as Stardust@Home — like zombies, the Zoo is interested in your brains. The original idea was simple and, in execution, habit-forming.

Volunteer participants see one of a million galaxies from the SDSS and classify it as elliptical, one of three spiral orientation classes, a merging system, or something else. Hoping for a few thousand participants to finish looking at all these galaxies over perhaps a year, the project's immediate success left the team scrambling to keep adequate computing resources available. Less than 3 years after the Zoo's initial computer crashes, nearly a quarter of a million participants have provided more than 60 million total classifications.

The project team was initially flooded with too many e-mail queries to answer. So they set up a discussion forum hoping users could help each other when the team couldn't respond. This forum not only has served as a venue to share experiences and help newcomers, but it also has been a source of additional scientific results and a way to form a tight-knit community of users ("Zooites," as they came to call themselves, in distinction to the "Zookeepers" who run the project).

The original idea was simple and, in execution, habit-forming.

Less than 3 years after the initial computer crashes, nearly a quarter of a million participants have provided more than 60 million total classifications.

Zooites started posting interesting galaxies for comment, questions about classification, and science musings. This is about the time I joined the Zoo, and eventually became part of the science team after noticing that some possible galaxy mergers were more likely to be non-interacting galaxies that appear to "overlap" despite their great distance.

Some of the Zoo's popularity traces to smart decisions, and a bit of luck, in its setup. The classification interface is clean and needs only limited comprehension of English. Wondering whether the next galaxy will be a big, beautiful spiral or a teeming cluster creates some of the suspense of a video game and keeps Zooites clicking for more. The Zookeepers discovered how important these features were when moving to Zoo 2, which asks more detailed questions about the brightest galaxies. Incorporating new lessons about the interfaces with feedback from users, and doing so before many Zooites lose interest, proves to be a sometimes tense challenge.

Besides accomplishing significant science by helping astronomers classify galaxies, the Galaxy Zoo project has also created a "galaxy font" using actual galaxies. SDSS, Galaxy Zoo Team

The human element

As Zooites have learned about galaxies (as well as stars, clusters, and nebulae), the Zookeepers have learned about dealing with Zooites. Several guiding principles emerged: Zooites are collaborators, not "users." They should be kept fully informed of project activities, and all projects should have genuine research goals rather than including simple busywork ("no clicks wasted"). Dealing with a wide range of people in the forum also has proven instructive, and the team leaders compare it to a crash course in applied psychology.

Why not just let a computer do all this? The SDSS data were all evaluated automatically to find objects, separate stars from galaxies, and quantify the match between each image and various kinds of galaxy structures. Astronomers and computer-science specialists have put considerable effort into automating the assessment of objects in astronomical images, both to make the process impersonal and to survey the ever-larger data sets that the new instruments delivered. Still, for many of these tasks, software leaves much to be desired.

Identifying fragmentary spiral patterns, distinguishing galaxies distorted by interaction from those only overlapping along the line of sight, and identifying which distinct objects in an image might be parts of a single galaxy — all are tasks for which people have proven more accurate after just brief practice. In fact, the

The Sloan Digital Sky Survey used New Mexico's Apache Point Observatory to map more than a quarter of the sky, including several sights still unseen by human eyes. The Galaxy Zoo project aims to have human volunteers classify many of the galaxies in these images, helping astronomers find interesting objects and phenomena to do follow-up research on. Fermilab Visual Media Services, www.sdss.org

"What's the **blue stuff** below? Anyone?" — Hanny van Arkel

Hanny's Voorwerp (Dutch for "Hanny's Object") may be Galaxy Zoo's most famous discovery. When a Dutch schoolteacher saw unusual "blue stuff" below galaxy IC 2497 (at left), she posted the picture and asked for feedback. Despite more intricate observations from Kitt Peak National Observatory's 3.5-meter WIYN telescope (at right), its nature remains mysterious. SDSS; William Keel and Anna Manning

next round of upgrades has used the Galaxy Zoo results to help train the software to be even faster and more accurate, completing the next step in the spiral of the human-machine partnership.

Science at your fingertips

The Zooites have by now exceeded all of the Zoo's original science goals. They have identified red spirals and blue ellipticals, outliers to the general rules connecting galaxy form and content. The Zoo has shown differences in the growth history of massive black holes between spiral and elliptical galaxies, and contributed to the known characteristics of merging galaxies.

Additional science results have arisen from objects posted by participants for discussion on the project forum — these include overlapping galaxies suitable for measuring dust absorption and the giant ionized gas cloud known as Hanny's Voorwerp, the signature discovery of the Zoo. Although several dozen users had earlier seen the galaxy IC 2497 for classification, it drew special attention only after a couple of weeks when Dutch elementary school teacher Hanny van Arkel posted its image on the forum and asked simply, "What's the blue stuff below? Anyone?"

The Zookeepers collected available information to constrain speculation on its nature until it was clearly time for new data. Colleagues from the U.K. to California obtained light measurements that showed this to be a cloud of gas tens of thousands of light-years in extent, illuminated by an unseen quasar (the superenergetic centers of some galaxies). These measurements set off further programs aimed at examining it in other wavelengths, from radio to X-ray.

By now, Hanny's Voorwerp (the Dutch word for object, albeit not usually used in this context) has undergone examinations from additional ground-based optical telescopes, a continent-wide network of European radio telescopes, the Westerbork and MERLIN radio arrays, Kitt Peak's WIYN telescope, the Hubble Space Telescope, the GALEX spacecraft, the Swift and Suzaku X-ray telescopes, and the XMM-Newton X-ray observatory.

The current data allow two possibilities, both unprecedented — either the nearest quasar lies behind so much obscuring gas and dust that even X-ray surveys have failed to find it, or it has virtually turned off within the past 80,000 to 100,000 years. Either conclusion has a strong impact on how we think about quasars and their occurrence in galaxies.

The nearest analogs to Hanny's Voorwerp are giant ionized gas clouds occasionally seen on the outskirts of active radio galaxies, where powerful ultraviolet radiation encounters unusually dense gas. Zoo participants have proven able to pick these out by their unusual colors in the SDSS images, adding considerably to the known sample and strengthening the points of comparison for Hanny's Voorwerp. Some participants worked with me to set up a "Voorwerpje hunt" (the Dutch diminutive form of Voorwerp), in which at least 10 people examined 15,000 active galaxy candidates within a 6-week period. This sort of screening approach, with objects culled for further inspection by the science team, has proven to be a powerful specialty of Galaxy Zoo.

Some projects have arisen strictly because of interest among Zooites, independent of the science team. Most notable so far has been identifying a class of compact galaxies with extremely high star-formation rates, the "Peas." Follow-

up observations began only after a group of Zooites gathered the SDSS data and made the case to the Zookeepers. Further projects of this kind involve irregular galaxies and nearby high-velocity stars.

The depth of interest has been amazing: Some volunteers have learned database query protocols and scripting languages to be able to winnow through the SDSS database on their own for these programs, and have even been co-authors on science papers reporting the results. The ownership Zooites show in the entire project has been another impressive, and mostly unexpected, outcome, reflected in the number of research papers (11) that include Zooites as authors.

The future Zoo

The Zoo is now in its second phase, with participants contributing more refined classifications of bright galaxies. At a broader level, it has expanded its scope to the "Zooniverse," embracing additional astronomical projects.

A new application, Merger Zoo, allows users to compare simulations of merging galaxies to actual images (another task at which people still prove to be much better than software). The participants zero in on the best matches before performing more detailed, and time-consuming, simulations to unravel the galaxies' physical properties. Supernova Zoo puts people in the action practically as it's happening, picking out supernovae from false positives before large telescopes follow up with spectroscopic analysis, while Solar Storm Watch lets users track any solar outbursts seen by the twin STEREO spacecraft. Hubble Zoo has gone live, extending this approach to the distant universe using the rich Hubble Space Telescope archive, as has Moon Zoo, which uses Lunar Reconnaissance Orbiter images to map the history of the Moon via counts of craters and boulders.

As part of the Citizen Science Alliance, the Zoo team is also investigating non-astronomical applications of its methodology and information infrastructure — discussions have included animal behavior and papyrus reconstruction. Looking ahead within astronomy, it has become clear that the human-machine partnership will have to change shape yet again with future projects such as the Panoramic Survey Telescope & Rapid Response System (Pan-STARRS) and the Large Synoptic Survey Telescope (LSST). With such mammoth surveys, more intense than any that have come before, Galaxy Zoo's efforts will be best used to train and check on automated routines, as well as examine oddities flagged automatically.

It's fun and it's educational, so why not join us on a field trip to the Zoo and see for yourself?

A 2009 meetup in Greenwich, England, brought 40 Zooites together, 0.016 percent of the total. Despite few actually having careers in science, these volunteers have advanced astronomy significantly, sometimes even co-authoring papers in scientific journals. William Keel

Galaxy Zoo volunteers, or "Zooites," have helped classify these galaxies, a type known as "backlit" galaxies and of particular interest to astronomers. Galaxy Zoo brought the number of such galaxies from a few dozen to more than 2,000. William Keel and Anna Manning

Read "Making sense of galaxies" online at www.Astronomy.com/toc.

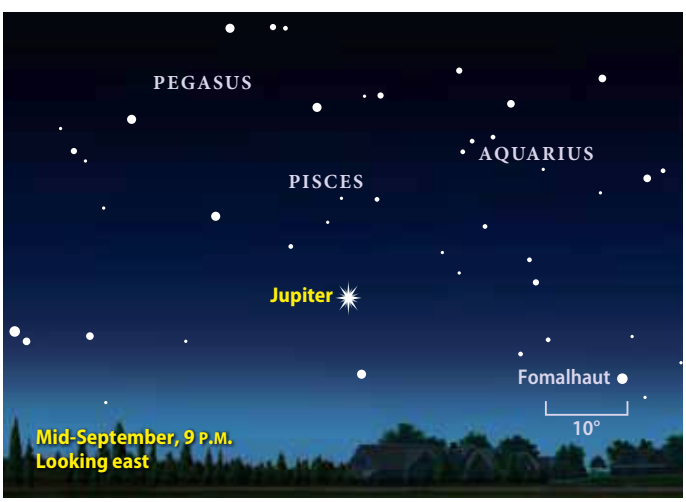
The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

September 2010

Jupiter rules the night

Jupiter's colored cloud tops are a treat for anyone who views them through a backyard telescope. NASA/JPL/University of Arizona



Jupiter shines brilliantly in the eastern sky after sunset as it reaches the peak of its 2010 apparition. *Astronomy*: Roen Kelly

With the hottest days of summer behind us and nightfall arriving earlier, conditions couldn't be better for evening skygazing. For those under rural skies, the bright Milky Way stretches overhead. But even city dwellers can enjoy planet hunting. Four of the five brightest planets, along with all the dimmer ones, appear in the evening sky. Only Mercury lies in the east before dawn.

Mighty Jupiter dominates the sky nearly all night as it makes its best appearance in nearly 50 years. September is also a prime time for viewing Uranus, although you'll need binoculars to see it clearly. The seventh planet lies within 2° of Jupiter all month. The eighth planet, Neptune, lies about 30° west of this pair. Closer to home, Venus and Mars lie in evening twilight near Virgo's brightest star, Spica.

But our tour of the night sky begins even lower in the twilight, where you might glimpse **Saturn** in early September. On the 1st, the ringed planet sets just 1 hour after the Sun and stands barely 5° high in the west 30 minutes after sunset.

Use Venus as a guide. This brilliant planet pops out of the twilight minutes after sunset. Then look for Spica 1° to Venus' upper right. Because Saturn and Spica both glow at magnitude 1.0, if you can see Spica, you might be able to spy Saturn. The planet lies about 20° to Venus' right and at roughly half the brighter planet's altitude. See how far into September you can follow the ringed planet — you'll be lucky to track it beyond the first week.

Venus appears dazzling after sunset from its perch low in the west-southwest. On the 1st, it lies in line with Spica and Mars, with the star between the planetary pair. Two evenings later, Spica appears midway between the planets. The three objects form an ever-widening triangle as the month progresses. Venus shines far brighter than Spica, which, in turn, glows a little brighter than Mars.

— Continued on page 41

36 Jupiter at its best
41 Meteor watch
41 Rising Moon
42 When to view the planets
42 Jupiter's moons on the move
42 Comet search
43 Locating asteroids
43 Uranus joins Jupiter

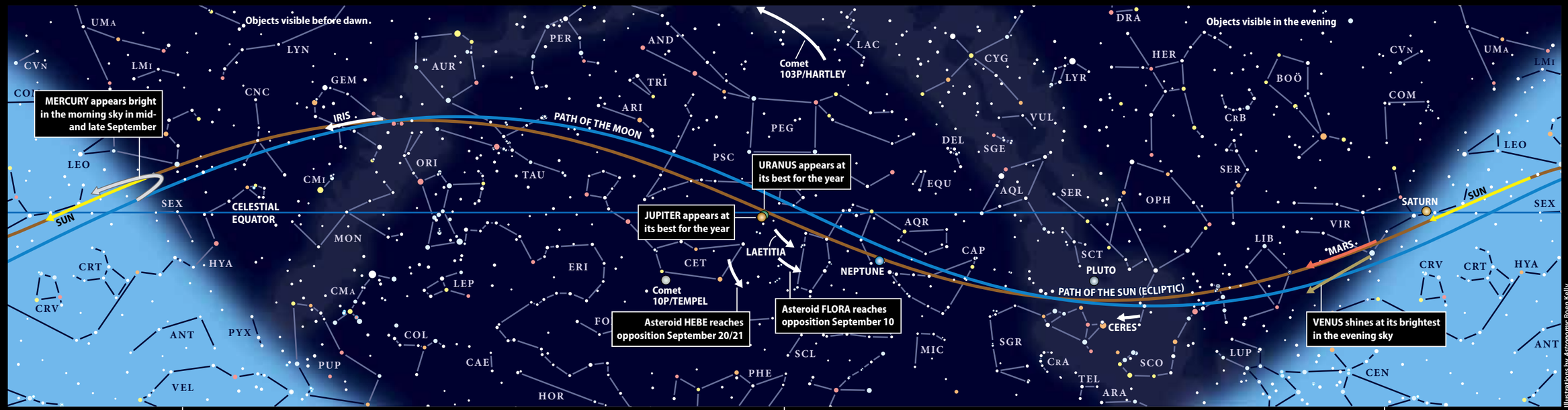
Visible to the naked eye
Visible with binoculars
Visible with a telescope

Planets in September 2010

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

Path of the planets

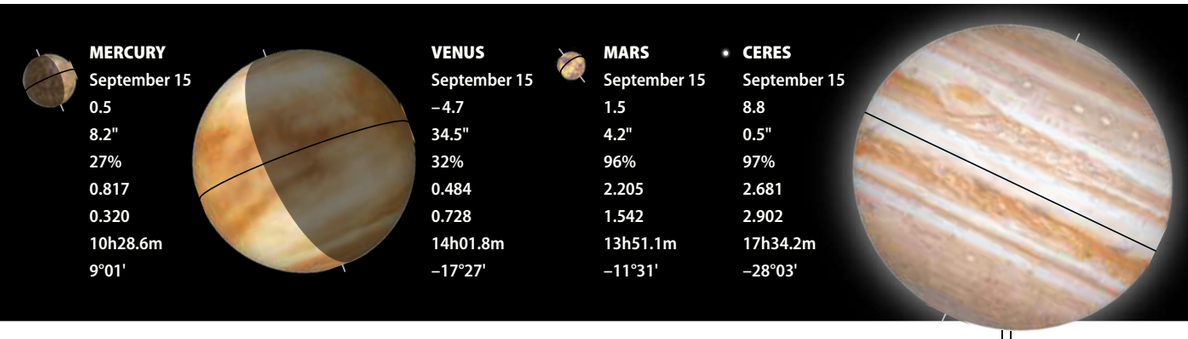


Illustrations by *Astronomy*: Roen Kelly

MOON PHASES

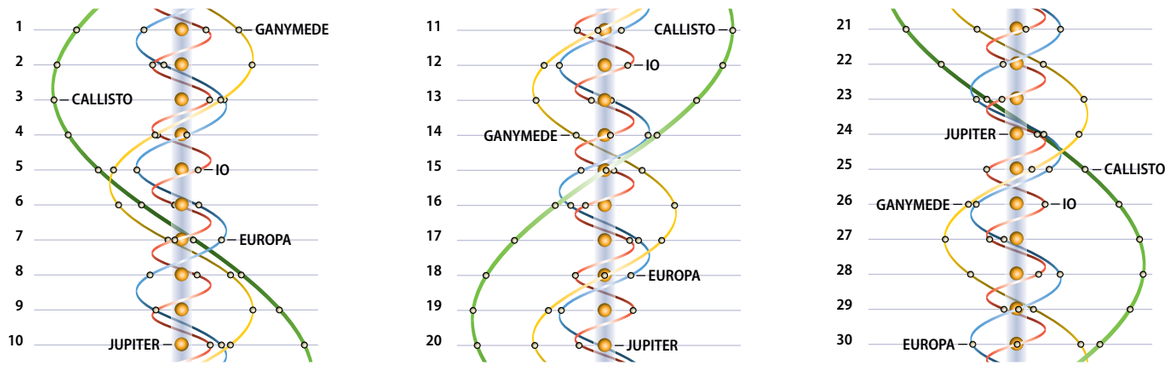
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	September 15	September 15	September 15	September 15	September 15	September 1	September 15	September 15	September 15
Magnitude	0.5	–4.7	1.5	8.8	–2.9	1.0	5.7	7.8	14.0
Angular size	8.2"	34.5"	4.2"	0.5"	49.8"	15.9"	3.7"	2.3"	0.1"
Illumination	27%	32%	96%	97%	100%	100%	100%	100%	100%
Distance (AU) from Earth	0.817	0.484	2.205	2.681	3.959	10.448	19.093	29.106	31.696
Distance (AU) from Sun	0.320	0.728	1.542	2.902	4.958	9.548	20.092	30.017	31.898
Right ascension (2000.0)	10h28.6m	14h01.8m	13h51.1m	17h34.2m	23h59.2m	12h18.0m	23h56.5m	21h55.5m	18h11.1m
Declination (2000.0)	9°01'	–17°27'	–11°31'	–28°03'	–1°49'	0°25'	–1°14'	–13°09'	–18°33'



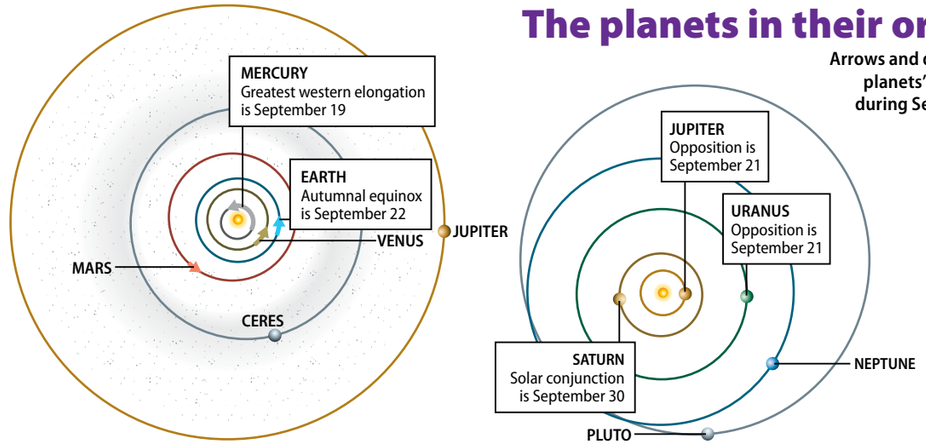
Jupiter's moons

Dots display positions of Galilean satellites at 4 A.M. EDT on the date shown. South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during September.



StarDome

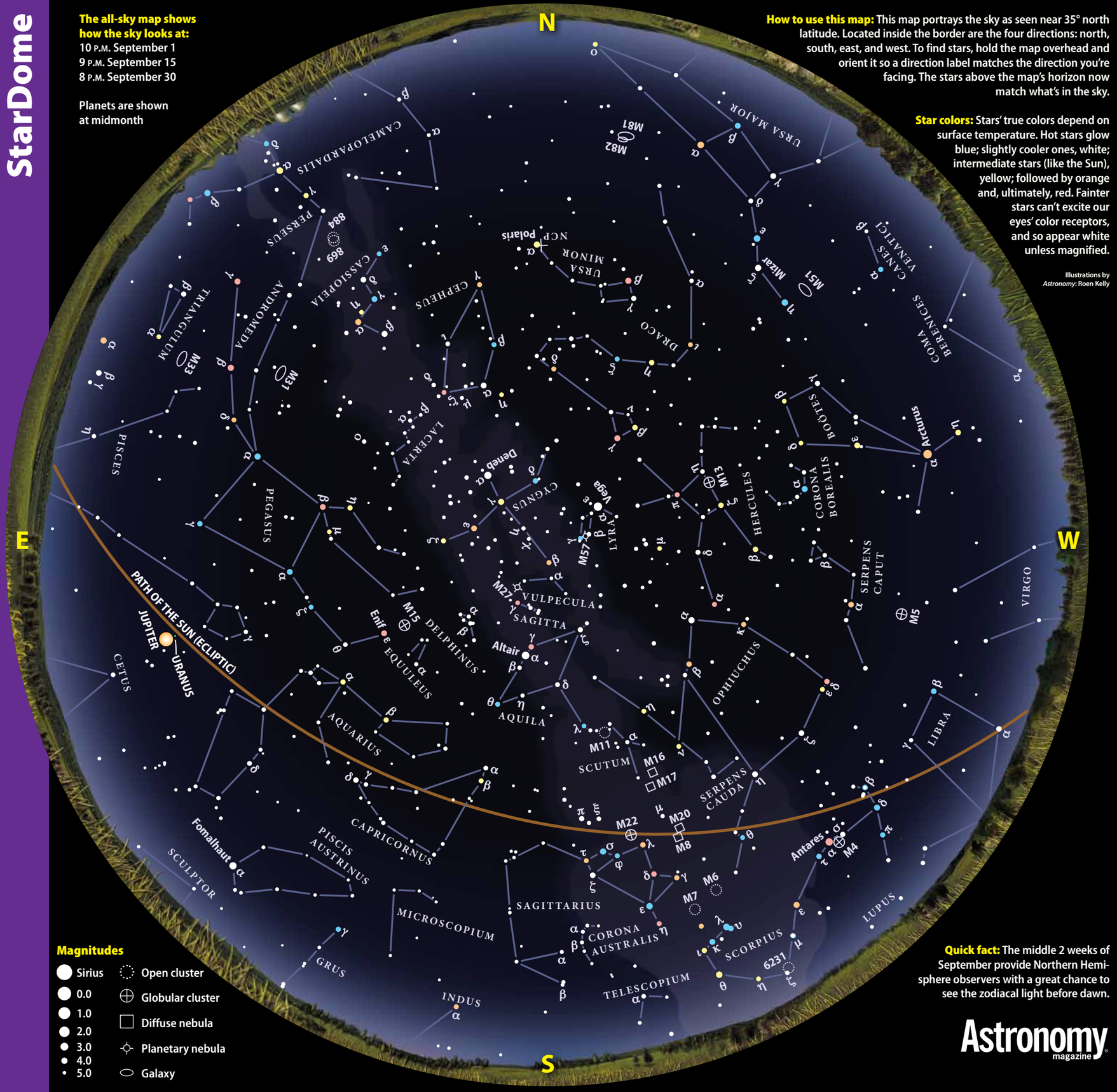
The all-sky map shows how the sky looks at:
10 P.M. September 1
9 P.M. September 15
8 P.M. September 30

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: The middle 2 weeks of September provide Northern Hemisphere observers with a great chance to see the zodiacal light before dawn.

Astronomy magazine

September 2010

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

Calendar of events

1 Last Quarter Moon occurs at 1:22 P.M. EDT

Venus passes 1.2° south of Spica, 2 P.M. EDT

3 Mercury is in inferior conjunction, 9 A.M. EDT

4 Mars passes 2° north of Spica, 10 A.M. EDT

7 The Moon is at perigee (221,948 miles from Earth), 11:58 P.M. EDT

8 New Moon occurs at 6:30 A.M. EDT

9 The Moon passes 8° south of Saturn, 6 P.M. EDT

10 Asteroid Flora is at opposition, 11 P.M. EDT

11 The Moon passes 5° south of Mars, 4 A.M. EDT

The Moon passes 0.3° south of Venus, 9 A.M. EDT

14 Asteroid Laetitia is at opposition, 6 A.M. EDT

15 First Quarter Moon occurs at 1:50 A.M. EDT

19 Mercury is at greatest western elongation (18°), 1 P.M. EDT

20 The Moon passes 5° north of Neptune, noon EDT

21 Asteroid Hebe is at opposition, 2 A.M. EDT

21 The Moon is at apogee (252,379 miles from Earth), 4:02 A.M. EDT

Jupiter is at opposition, 8 A.M. EDT

Uranus is at opposition, 1 P.M. EDT

Special observing date

21 Jupiter shines brighter (magnitude –2.9) and appears larger (49.9" across) than at any time since October 1963.

22 Jupiter passes 0.9° south of Uranus, 3 P.M. EDT

Autumnal equinox occurs at 11:09 P.M. EDT

23 Full Moon occurs at 5:17 A.M. EDT

The Moon passes 7° north of Jupiter, 7 A.M. EDT

The Moon passes 6° north of Uranus, 7 A.M. EDT

Venus is at greatest brilliancy (magnitude –4.8), 4 P.M. EDT

29 Venus passes 6° south of Mars, 2 A.M. EDT

30 Saturn is in conjunction with the Sun, 9 P.M. EDT

Last Quarter Moon occurs at 11:52 P.M. EDT

See tonight's sky in Astronomy.com's STARDOME

— *Continued from page 36*

A crescent Moon joins the trio September 10. Mars stands 6° directly above the Moon with Venus an equal distance to Mars' lower left. By the following night, September 11, the Moon has moved 6° to Venus' left.

Although Venus dips closer to the horizon during the second half of September, it remains a beacon. It reaches its greatest brilliancy for this evening apparition September 23, when it blazes at magnitude –4.8. That evening, it sets 1 hour after the Sun.

Despite its relatively low altitude, Venus appears fascinating through a telescope. Look for rapid changes in both its size and phase. On September 1, the planet shows a disk 29" across and 41 percent lit. By the 30th, this fat crescent has slimmed to a slender 19 percent illumination, while the planet's diameter has swelled to 45".

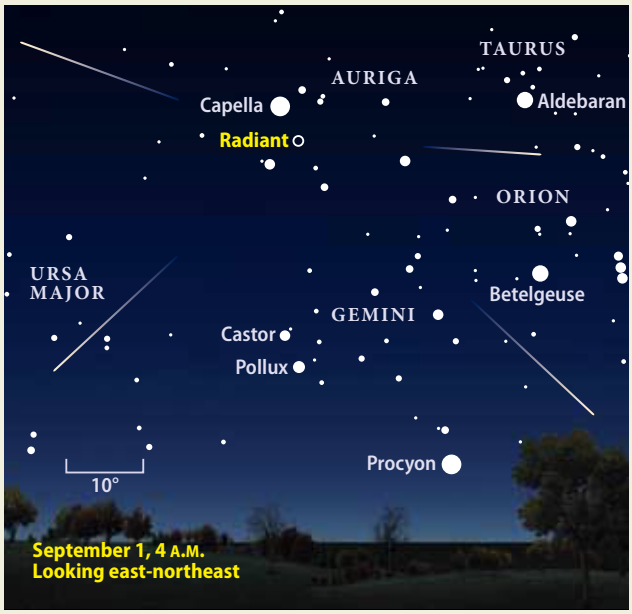
Martin Ratcliffe *provides professional planetarium development for Sky-Skan, Inc., in Nashua, New Hampshire. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

In contrast to big, bright Venus, **Mars** appears small and dim. The Red Planet glows at magnitude 1.5 all month — some 300 times fainter than Venus. And Mars' disk measures a paltry 4" across and shows no detail through a telescope. The planet won't improve significantly until late next year.

If you haven't seen **Pluto** before, September offers an exciting opportunity. The distant world performs an elegant loop in northwestern Sagittarius close to an 8th-magnitude star. And this star lies only 2.6° north-northwest of 4th-magnitude Mu (μ) Sagittarii. Pluto's path normally takes place against a backdrop of faint stars, making it hard to home in on the 14th-magnitude dwarf planet. But Pluto's current proximity to a relatively bright star makes the task much easier.

Still, you'll need at least an 8-inch scope and a dark sky to see Pluto visually. (You also can track it with a CCD camera attached to a small scope.) Pluto begins the month 4' northeast of our guide star. It then heads southwest, passing just 32" due east of the star September 12. Pluto then

Meteor watch



The Alpha Aurigid shower peaks in early September, when viewers can expect to see up to six meteors per hour. *Astronomy:* Roen Kelly

Riding along in a chariot

September ranks among the leanest months for meteor viewing. A few minor showers and occasional sporadic meteors brighten the night, however, so observers should keep an eye to the sky.

Perhaps the most intriguing September shower is the Alpha Aurigids. This shower peaks before dawn September 1, which coincides with a Last Quarter Moon. Although the relatively bright Moon will hinder observations, the shower still should be worth a look. The zenithal hourly rate — the rate a person would typically see under a dark sky if the shower's radiant were overhead — peaks at six per hour. But the shower delivered an unexpected 130 meteors per hour in 2007. No one knows when the Alpha Aurigids could surprise us again.

Rising Moon

Head to the edge of the Moon's craggy face

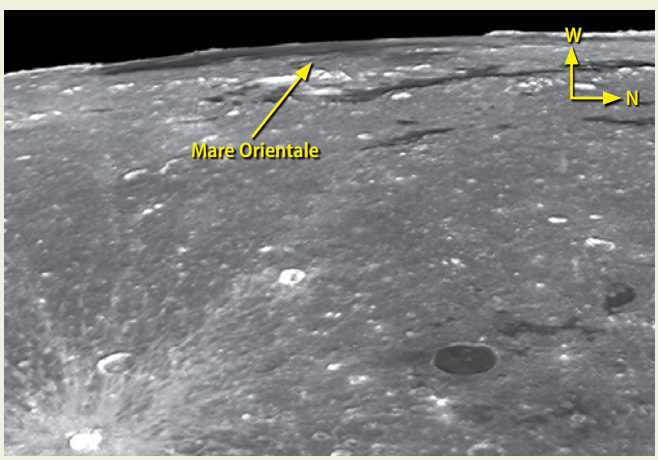
Earthbound observers usually have to work to get good views of features along the Moon's limb. But September provides a rare chance to see multiple limb sections in a single calendar month.

As the crescent Moon waxes from the 11th to the 13th, note how far Mare Crisium appears from the eastern edge. On the limb, look for the elongated dark patches of Mare Smythii and Mare Marginis. Near the southeastern limb, you'll see only bright highlands. That changes by the 18th, once the mottled Mare Australe has rotated into view.

A few nights later, the bumpy south polar region displays some nice 3-D shadow effects. Crank up the power for a close look. At the same time, notice how maria Smythii and Marginis have disappeared.

At Full Moon September 23, Mare Orientale comes into view along the western limb. This magnificent impact basin offers multiple rings and lava lakes with the good timing of the next few nights. At first the rings appear in profile, but our orbital perspective soon changes to reveal the lava ponds of Lacus Veris and Lacus Autumni.

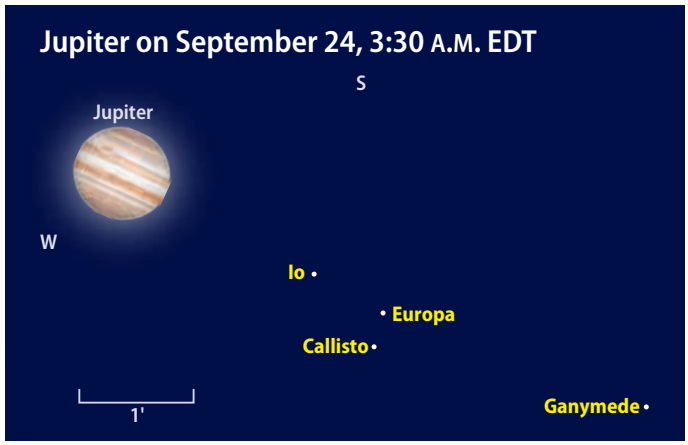
Astronomers call this tilting and turning of the Moon libration.



Mare Orientale sits on the Moon's western limb, where it comes into view at favorable librations. Moon watchers can get a good look starting September 23. Robert Reeves

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Venus (southwest)	Jupiter (southeast)	Mercury (east)
Mars (west)	Uranus (southeast)	Jupiter (west)
Jupiter (east)	Neptune (south)	Uranus (west)
Saturn (west)		
Uranus (east)		
Neptune (southeast)		



All four Galilean moons group together to the east of Jupiter the morning of September 24. *Astronomy:* Roen Kelly

reverses direction and starts moving to the southeast. By the 30th, it has traveled 7' from the star.

Neptune lies in the northeastern corner of Capricornus the Sea Goat, some 50° east of its neighbor Pluto. This region of sky appears bland compared with the Milky Way riches to the west, but you should be able to spot the 3rd-magnitude star Delta (δ) Capricorni with naked eyes from the suburbs. Neptune lies 3.5° northeast of Delta in mid-September and just 0.7° northeast of 5th-magnitude Mu Cap.

Using binoculars, place Delta near the lower right edge of the field of view. You then should have no trouble spotting Mu and Neptune near the field's center. Neptune glows at magnitude 7.8, about 10 percent of Mu's brightness. A telescope reveals Neptune's blue-gray disk, which measures 2.3" across.

Although Neptune may be small and faint, you can't say the same about our next target, **Jupiter**. The giant planet reaches opposition and peak visibility in September. And this is no ordinary opposition. Next March, Jupiter reaches perihelion — the closest point to the Sun during its 12-year orbit — so it lies closer to Earth at this opposition than at a typical one.

In fact, this is Jupiter's finest appearance in 47 years. Not since October 1963 has the giant planet appeared as big and bright. At opposition September 21, Jupiter shines at magnitude –2.9 and its equator spans 49.9". And because it now lies opposite the Sun in our sky, Jupiter remains visible all night. You can find it rising in the east as darkness falls, below the Circlet asterism in the constellation Pisces the Fish.

For the best views through a telescope, wait until Jupiter climbs high in the south in late evening. Marvel at the atmospheric features visible on the disk — it won't get better than this.

For experienced Jupiter-viewers, the planet looked oddly asymmetric during the first half of 2010. Normally, a pair of globe-spanning dark equatorial belts straddle a brighter equatorial zone. But the South Equatorial Belt (SEB) essentially disappeared early this year — and no one knows why. Some planetary scientists think that an overlying layer of cirrus clouds, which on Jupiter consist of ammonia-ice crystals, may be masking the SEB.

The SEB has disappeared before for varying lengths of time. But what observers look forward to the most is the belt's inevitable return. In the past, such revivals often have been impressive, with storms erupting suddenly and dra-

Comet search

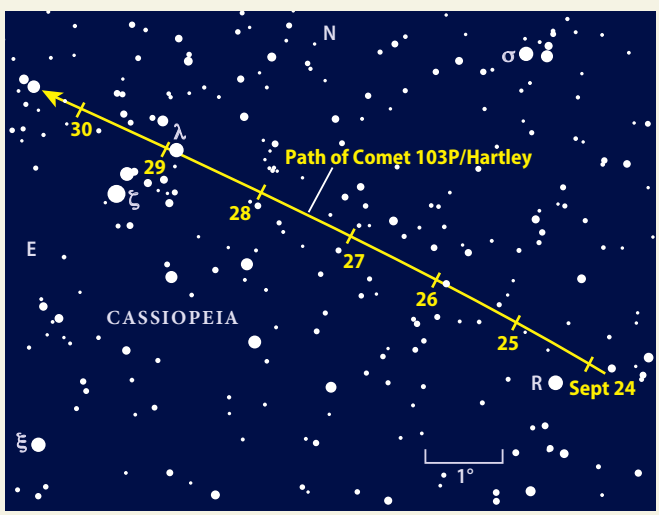
The start of something wonderful

Comet 103P/Hartley could hit the headlines in the next 2 months. First, the comet comes closest to both the Sun and Earth in October's second half, when observers should get nice views through binoculars and telescopes and might glimpse it with naked eyes. Then, in early November, NASA's Deep Impact spacecraft will fly past the comet.

Currently, Comet Hartley is brightening quickly as it approaches Earth. Astronomers expect it to reach 10th magnitude by late September. The best views will come under a dark sky starting around the 24th. The comet then lies in Cassiopeia, south of that constellation's familiar W-shaped asterism, and remains visible all night.

The comet is making its fourth return since Australian Malcolm Hartley discovered it in 1986. This short-period comet loops through the inner solar system every 6.5 years.

During the spacecraft's flyby, onboard cameras will reveal the sources of the dusty jets on the comet's nucleus. Through earthbound telescopes, observers often see a pinprick of light at the center of a comet's glow. Astronomers call this a "false nucleus," and it hides the comet's true surface. NASA's probe will be able to pierce this shroud.



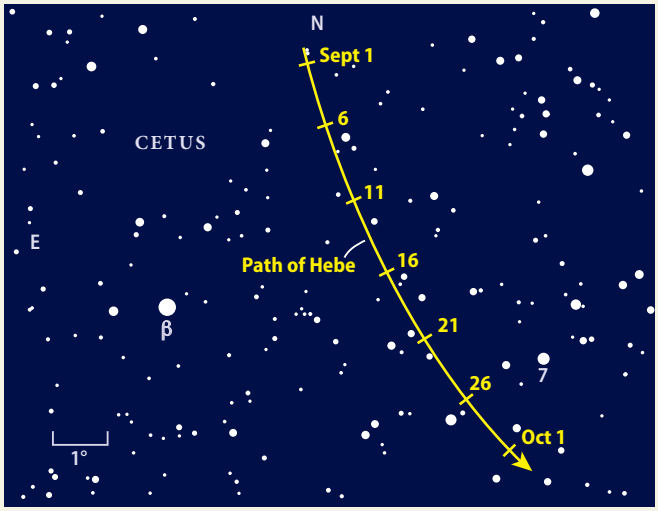
Comet 103P/Hartley arcs high in the sky on September evenings, when it should be a fine sight through binoculars. *Astronomy:* Roen Kelly

Hebe puts on a whale of a show

Hundreds of thousands of minor planets revolve around the Sun, but only a handful are big enough or close enough to track through a 4-inch telescope. In September, asteroid 6 Hebe stands out as the best. It reaches opposition and peak brightness on the 21st, when it glows at magnitude 7.7. The best views will come when it lies high in the sky around local midnight.

After you observe Jupiter and Uranus (which coincidentally reach opposition the same day as Hebe), drop south to the 2nd-magnitude star Beta (β) Ceti. Then, shift approximately 5° west using the multitude of conveniently spaced fainter stars. The chart will help you zero in on the rocky asteroid, which spans some 120 miles.

Astronomers knew of only five minor planets before German amateur astronomer Karl Hencke discovered Hebe in 1847. (Hencke also discovered the fifth such object, Astraea, 19 months earlier.) By the turn of the 20th century, asteroids were appearing so frequently on photographic plates that astronomers started calling them "vermin of the skies." Because Hebe currently lies in the constellation Cetus the Whale, "krill" seems to be a more appropriate description.



Asteroid Hebe skims through the waters of Cetus the Whale, not far west of the 2nd-magnitude star Beta (β) Ceti. *Astronomy*: Roen Kelly

matically. The revival could happen within a couple of months — or take a couple of years. The only certainty is that if you don't keep a watch on Jupiter, you won't see the eventual spectacle.

Far above Jupiter's atmosphere, four bright moons continually orbit the giant planet. It's fun to track the motions of these so-called Galilean moons — Io, Europa, Ganymede, and Callisto — that the great Italian scientist discovered 400 years ago. Usually, you'll see at least one moon on both sides of the planet, but occasionally all four line up on the same side. A good example occurs the morning of September 24, when the quartet appears east of Jupiter.

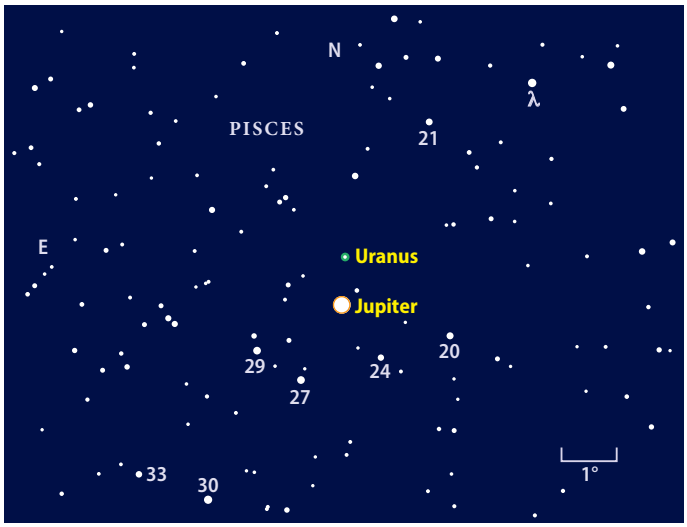
The moons also play cat-and-mouse with Jupiter. Once each orbit, a moon passes in front of the planet and observers can watch the small moon transit the giant disk. For all the moons except Callisto, their shadows also transit the planet. It's far easier to see a moon's dark shadow than its brighter disk against Jupiter's bright cloud tops.

With Jupiter near opposition and the Sun and Earth nearly aligned in the giant planet's sky, a moon and its shadow transit close to each other.

On September 7, for example, Io's shadow begins to transit at 12:52 A.M. EDT, and Io itself follows 23 minutes later. A week later, on the 14th, only 12 minutes separate the shadow and moon transit. (The shadow first touches Jupiter's disk at 2:47 A.M. EDT.) And at opposition September 21, the two transit simultaneously beginning at 4:42 A.M. EDT.

While you're in Jupiter's vicinity, take a few minutes to view **Uranus**. The distant planet lies less than 1° north of Jupiter. You might guess from their proximity that the two planets would lie opposite the Sun in our sky at about the same time. You'd be right: Uranus reaches opposition just 5 hours after Jupiter.

At magnitude 5.7, Uranus glows bright enough to see with naked eyes from under a dark sky. Binoculars easily reveal it in the same field as Jupiter. A telescope at high magnification shows Uranus



Blue-green Uranus lurks almost in Jupiter's shadow. You can find the distant world less than 1° north of brilliant Jupiter September 21, when they both reach opposition. *Astronomy*: Roen Kelly

has a 3.7"-diameter disk with a distinctive blue-green hue.

The best morning views of **Mercury** this year occur in late September. Mercury reaches greatest elongation September 19, when it lies 18° west of the Sun. You might spot Mercury as early as September 13, the day it climbs to magnitude 1.0 and lies 6° below Regulus, Leo's brightest star. Through a telescope that morning, Mercury appears 9" across and just 21 percent lit.

The inner planet brightens quickly, reaching magnitude –0.4 by the 19th. It then rises more than an hour before the Sun and shows a 7"-diameter disk that's about half-lit. Mercury quickly loops back toward the Sun, although you can follow it through the end of the month if you have an unobstructed eastern horizon. On the 30th, it shines at magnitude –1.1 and a scope reveals a fat gibbous disk measuring 6" across.

LETTER TO GALILEO

HOW ASTRONOMY OVER THE PAST

If Galileo could see us now, what would he think about our study of the cosmos?

by Chris Impey

While lost in thought, I dream that Galileo Galilei is beside me, in the flesh. He looks at me quizzically and asks me to describe what astronomers have been doing in the 400 years since he published the first telescopic observations in Sidereus Nuncius. *This is my description.*

Galileo, I don't know where to start. Your humble spyglass turned the world upside down, cementing the Copernican revolution and removing Earth from the universe's center. You know all this, but I doubt you could have imagined how far we have taken the technology.

Your reputation? Huge. You are an icon, a "rock star" of science, known by your first name and considered the earliest true experimental scientist. (I should tell you, most people think you invented the telescope.) I'm happy to give you your due, but let me chastise you a bit, too. You made trouble for yourself by belittling your opponents and ignoring the invitations of your colleagues to live where you could hold the Copernican view without repercussion. And did you have to ignore the requests of Johannes Kepler for one of your telescopes? It seems ungrateful, given that he tried to intercede on your behalf with the Catholic Church.

But back to the point at hand. Many scientists and their discoveries have carried astronomy through the past four centuries. There's much we've learned about the planets and nearby stars. And we've discovered just as much about galaxies outside our own, and the universe as a whole.

Titans of telescopes

A year after you died, Isaac Newton was born in England. He would take your observations of falling objects and your notions of inertia and incorporate them into a universal theory of gravity. He also made the next leap in telescope design by using an idea you had toyed with — a concave curved mirror to gather and focus light — and perfecting its design. All research telescopes now use mirrors instead of lenses. The largest built to your specification is at the Yerkes Observatory in southeast Wisconsin. Wisconsin? It's close to the center of a country in the New World. This 1-meter (that's about 1 yard) telescope is now more than 110 years old. I sense your displeasure. It's a shame you never met Newton. If you'll excuse me saying this, you both seem to be brilliant — and prickly.

You would have liked the clever German-born Englishman William Herschel, too. He was a craftsman with wide interests. You were a virtuoso with the lute, and I know it comforted you late in life when you were under house arrest and blind. Herschel played cello, oboe, and organ, and sometimes he rushed home during the intermission of a concert to squeeze in a few astronomical observations. Like you, Herschel made telescopes of aesthetic beauty as well as scientific power, with fine woods and delicate inlays.

New horizons

Observers in your time used telescopes to study the sky in visible light — this is what our eyes can detect. At the turn of the 19th century, Herschel discovered radiation beyond the red edge of the rainbow. Shortly after, we learned that there's also radiation beyond the blue edge. Now we know that visible light from red to blue is just a narrow sliver of a vast spectrum of radiation, from wavelengths the size of the smallest particles known to ones bigger than a person.

We didn't have the technology to collect and study these invisible waves until the middle of the 20th century,

YOUR HUMBLE SPYGLASS TURNED THE WORLD UPSIDE DOWN.

HAS CHANGED 400 YEARS

Galileo Galilei forged ahead in the scientific pursuit to understand our cosmos. Science Museum Pictorial

and now it's as if we have the whole piano keyboard to listen to rather than music made with two adjacent notes. I can see this excites you. From these different types of light, we've found that the invisible universe is a wondrous place of intense gravity, stellar nurseries, and cosmic particle accelerators.

Also, Earth's atmosphere blurs and jumbles the light a telescope can gather, limiting the sharpness of its vision. Air absorbs many of the invisible radiation waves. Fifty years ago, we learned how to slip the bonds of Earth with rockets, and now some of our best tools are in orbit, or even beyond. For 20 years, the Hubble Space Telescope has been a wonderful facility for observing radiation unaltered by the atmospheric motion that impacted your observations. We named it after the man who discovered the universe is expanding.

You'd like the way we've shrunk the world in terms of communicating science. In your day, your beautiful drawings of mountains and craters on the Moon and spots on the Sun made it into the hands of less than 100 people. Hubble images have reached hundreds of millions around the world.

Yes, you're right, these toys are very expensive. NASA's Great Observatories (Hubble is one such project) have each cost more than a billion dollars. That's more than 6.7 million of your gold ducats. Hubble's successor, the 6.5-meter-wide James Webb Space Telescope, has cost 4 billion dollars so far and it's still 4 years from launch.

Webb? No, he's not a famous astronomer; you pay homage to patrons, and we pay homage to space agency administrators.

Big glass

Meanwhile, our earthbound telescopes are clustered on the highest mountaintops in the darkest places on the planet. For a while, we were stuck. George Ellery Hale built a series of large telescopes in the clear skies of Southern California (at the west side of the New World), culminating in the 5-meter on Palomar Mountain, which was the largest telescope for decades. Then, in the 1990s, the floodgates opened. Now there are 15 optical telescopes with diameters 6.5 meters or larger with more planned. Yes, it's mind-boggling.

Your best telescope gathered 100 times more light than the eye. The biggest we have now can capture 10 billion times more, bringing into view stars on the far side of the Milky Way and galaxies so distant that their light has taken 13 billion years to reach us. Telescopes are time machines, letting us see the universe when it was small and dense and youthful.

You were right in your intuition about light; its speed isn't infinite. Today, we use its speed to define a unit in astronomy: A "light-year" is the distance light travels in 1 year. It's about 9.5 trillion kilometers.

Like you, modern astronomers covet bigger and better glass. I'd love to show you the place under the University of Arizona's stadium (in the New World) where we make mirrors. There, in a huge rotating oven, 16 tons of glass heats to 1160 degrees Celsius (2120 degrees Fahrenheit) and is spun into a parabolic shape, cooled, and then polished to near-perfection. You remember the artifacts and image distortions on even your best telescope? Our 8.4-meter mirrors are so smooth that if one were the width of North America, its biggest imperfections would be no more than 2.5 centimeters (1 inch) high. Sorry, I'm boasting a bit.

Astronomers in the New World are planning behemoths of 30 meters, and Europeans have the gleam in their eyes

NOW WE KNOW THAT VISIBLE LIGHT FROM RED TO BLUE IS JUST A NARROW SLIVER OF A VAST SPECTRUM OF RADIATION.

Chris Impey *is a University Distinguished Professor of astronomy at the University of Arizona and a former vice president of the American Astronomical Society. His recent book,* How it Ends *(W. W. Norton & Company, 2010), is about the eventual end of everything, from the individual to the universe.*

to make a telescope with a mirror 40 meters wide, composed of hundreds of small segments. That's nearly the size of the Tower of Pisa, but a lot smoother!

Why do we need big glass? A good question. You made your discoveries by eye, where light is captured for a fraction of a second. Then, 150 years ago, we learned how to capture hours of light on a glass plate with chemicals. Thirty years ago we learned how to trap light on a chip of silicon. Many homes today have one or more of these devices; we call them CCDs, and the men who perfected them won the highest award in science last year — the Nobel Prize. CCDs are able to collect almost every light photon that falls on them, so the only way to see farther into space is to have larger telescopes to harvest more photons.

THE MOONS YOU NAMED AFTER THE MEDICI, WE NAMED AFTER YOU. ... TO YOUR EYES THEY WERE JUST DOTS OF LIGHT DANCING AT EITHER SIDE OF JUPITER. BUT WE'VE SEEN THEM UP CLOSE.

When perfect detectors sit behind large parabolic reflectors, we can do some amazing things. We could read the date on a coin on the Moon's surface. Assuming it had air to fuel it, we could detect the light of a single flickering candle 1.5 million km (1 million miles) away.

The gamut of telescopes

We also learned the trick of taking separate telescopes and combining their light — scientists call this technique "interferometry." Astronomers first did this with radio telescopes, which observe radiation that's even farther on the red side than infrared. Now it's routine to have an interferometer with a resolution, if not the radio-gathering power, equivalent to an Earth-sized telescope. In fact, the dreams of many astronomers will require a small armada of telescopes in space working in synchrony. That way, we will be able to image earthlike planets dozens of light-years away and detect the gravity from supermassive black holes as their home galaxies merge into one.

Black holes? These are places with gravity so intense that not even light can escape. If the Sun's mass were squeezed to the size of the town of Pisa, it would be a black hole. The small ones form when a massive star dies, and the largest ones form from the stellar pile-ups at the centers of galaxies.

But don't think astronomers are acquisitive or greedy. We make excellent use of smaller telescopes, too. Amateur astronomers contribute important observations and cooperate with professionals to track comets and discover exploding stars called supernovae. They've even found planets beyond the solar system, some of which have been studied with 10cm telescopes. We currently know of more than 450 worlds orbiting other stars.

Distant worlds

You were spot-on in seeing the Moon as just another geological world like Earth, even though you paid a heavy price with the Catholic Church. Who won? You did, of course; you had truth on your side. I regret to say it, but it was 360 years after you were called to Rome and shown the instruments of torture before the Catholic Church admitted the mistake. Even so, Pope John Paul II bestowed on you some blame, saying the affair was marked by "tragic mutual incomprehension." It's sad; you're a devout man, and I see it pains you.

Since your time, we've visited the nearest worlds. The moons you named after the Medici to curry favor, we eventually named after you. And 20 years ago, scientists and engineers sent a spacecraft named Galileo on a 6-year voyage to Jupiter.

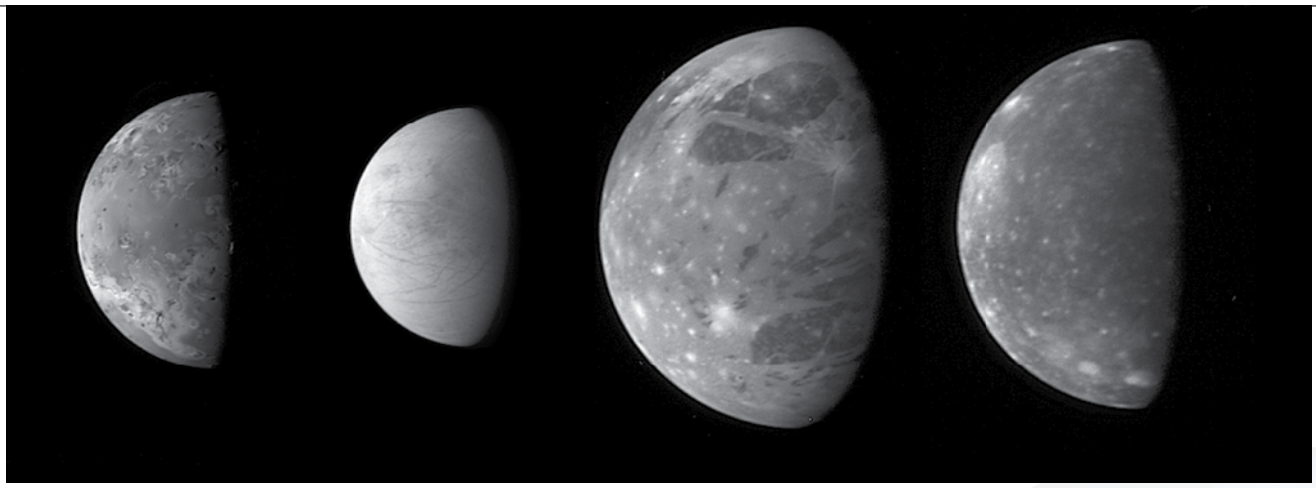
To your eyes, they were just dots of light dancing at either side of Jupiter. But we've seen them up close. Ganymede, with its grooves, ridges, and patches of light and dark, is bigger than Mercury. Callisto is old and pockmarked and may have a subsurface ocean. Europa is a true "water world" — its crumpled ice pack covers an ocean miles deep. Tiny Io is an oddity — a world of active volcanoes kept hot by the flexing of Jupiter's gravity grip. Io is a sulfurous, toxic place. Your arms are folded; you look stern. Ah yes, I remember now: You never agreed with the names German astronomer Simon Marius picked soon after you discovered the moons.

I have to tell you that the five planets that give their names to the days of the week are not the only ones in the solar system. Almost two centuries after your first observations with the telescope, William Herschel discovered Uranus, named after Saturn's father in Roman mythology. Uranus has irregularities in its orbit, which eventually led to the discovery of two more planets: Neptune and Pluto. They're named after the gods of the sea and the underworld. You enjoy a good argument, so I think you'd relish the heated debate that arose recently over the status of tiny, misbegotten Pluto. Like an interloper banished from the party, an international group of professional astronomers has demoted it to the status of a dwarf planet.

The invisible universe

Here's something you'll appreciate: Astronomers have not settled on just gathering light, or even the full radiation spectrum from high-energy gamma rays to low-energy radio waves. They've learned to see the universe in other ways. More ways than even I could have imagined when I was a boy falling in love with the night sky.

There are telescope arrays to monitor the effects of tiny high-energy particles that rain in on the upper



The Galilean moons is the nickname astronomers gave to Jupiter's four largest satellites because Galileo was the first to realize what they were. The moons (Io, Europa, Ganymede, and Callisto, from left to right) vary in size, composition, and appearance (not shown to scale). Scientists and engineers have sent probes to see the satellites and their planet up close, but none have yet sampled the moons' surfaces. Astronomers hope to launch such a mission in the next few decades. NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute

atmosphere. Some great cosmic centrifuge boosts these infinitesimal particles, called cosmic rays, until they have the energy of a well-flung fastball — or maybe I should say a well-tossed bocce ball.

There are telescopes so strange that they don't even look like telescopes. If you traveled to Earth's most southern landmass — called Antarctica — you'd see an array of detectors set into the pristine ice, reaching about 2.5 km (1.5 miles) down. Their goal is to detect particles called neutrinos — yes, "little neutral ones" in Italian. Neutrinos are so plentiful that there may be one for every particle in the universe, yet so ethereal that they pass through Earth as if it were not there. They come from the centers of stars and galaxies and maybe from the Big Bang, a time 13.7 billion years ago when the universe was a tiny dot of energy and crumpled space-time — modern theories state this is when the universe began.

YOU ENJOY A GOOD ARGUMENT, SO I THINK YOU'D RELISH THE HEATED DEBATE THAT AROSE RECENTLY OVER THE STATUS OF TINY, MIS PLUTO.

We even use the universe as a telescope. Remember when you came up with the first principle of relativity, where someone below the deck of a ship without windows couldn't tell if the boat was at rest or in constant motion? Well, a century ago a brilliant man named Albert Einstein revised your principle to take account of the fact that the speed of light is constant. His theory holds that space and time are supple, and gravity can distort them. As light moves through space, mass (which is mostly dark) slightly nudges the light to and fro. The amount of deflection is a measure of the mass the universe contains.

You look skeptical. I agree, it's a fantastic notion, but it does have a lot of experimental support.

Gravity eyes

Gravity, astronomy's final frontier. Imagine, Galileo, if we didn't have to look for light reflected off things or emitted by things, but could see the things themselves. We are close to detecting gravitational waves, the changes that ripple through space every time an object changes its shape or state. They arrive at Earth at the speed of light, and we look for them by detecting microscopic changes to a metal rod suspended in a near vacuum. These detectors push technology to the limit by looking for changes that are one part in 10 quadrillion — that's 10 followed by 15 zeros. Black holes, neutron stars, the early universe — all will be revealed in the harmonies of undulating space and time. This is our great ambition, to see the world with gravity's eyes.

How does it all work? Oh boy, your questions are coming often now. Cosmic rays, CCDs, neutrinos, gravitational waves, space travel, the Big Bang — the physics you knew wasn't wrong; it was incomplete. Technology has been our servant in mastering nature. I can't even think of where to start in trying to explain computers and the Internet. You once said, "Wine is sunlight, held together by water." Let's repair to a place where we can sip some wine, and you can catch up on four centuries of technological progress.

Astronomers declared 2009 the International Year of Astronomy. Read about some of the biggest events of the celebration at www.Astronomy.com/toc.

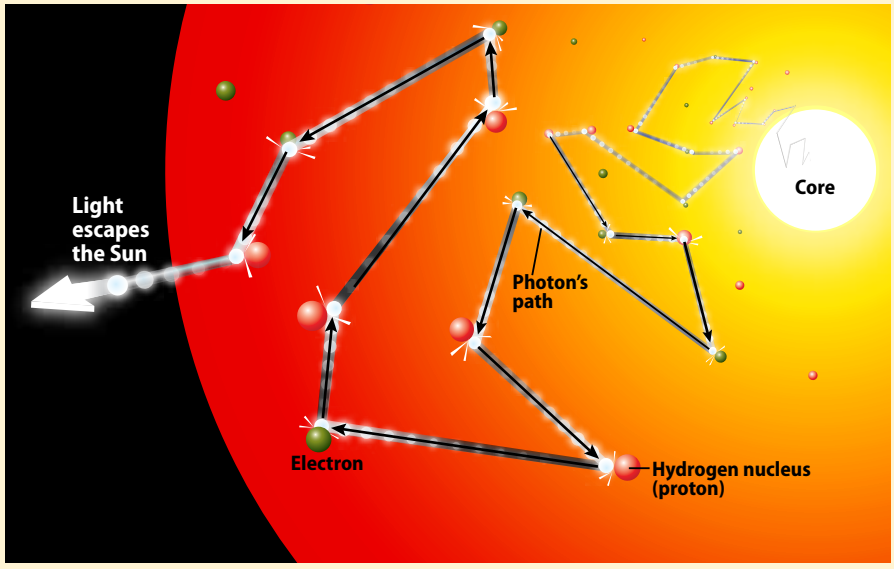
Ask Astro

Astronomy's *experts from around the globe answer your cosmic questions.*

Light's bumpy ride

Q: I heard that the light from nuclear fusion reactions in the Sun's core takes about 200,000 years to reach its surface. I thought the speed of light is constant. Why does it take so long?

— Tom Foltz, Lansing, Michigan



Astronomy: Roen Kelly

Nuclear reactions in the Sun's core produce light and other types of radiation. As light photons leave the core, they run into electrons and atomic nuclei, scattering off each one. These interactions cause photons to take, on average, 200,000 years to move from the Sun's core to its surface.

A: The speed of light is constant, but the problem is that the light (or more generally, radiation) doesn't travel directly from the Sun's center to the surface. This would take only about 2 seconds.

Think about a similar situation closer to home. When you look at a streetlight from a block away on a clear night, you can see directly to the light source — the bulb or gas tube itself. On a foggy morning, however, you might be able to only see a bright haze in the general direction of the streetlight. The light is still shining, of course, but instead of traveling directly to your eyes, fog droplets scatter (or deflect) the light, giving the light source a hazy appearance.

The light that originates at the Sun's core is scattered many times — sometimes toward the surface, sometimes back toward the core, sometimes sideways — before finally arriving at the surface and escaping into space. Electrons, atoms, and molecules in the Sun play the role of the fog droplets. The light travels at a constant speed, but it travels a greater distance as it scatters back and forth inside the Sun. When you look at a photograph of the Sun's surface, you are seeing the light's location the last time it was scattered before escaping. **— Ian Roederer,** Carnegie Observatories, Pasadena, California (after August 11)

EXTRASOLAR PLANETS

Q: With many new planet discoveries being hot Jupiters, is it possible that Mercury is the leftover core of a gas giant? — Patrick Clough, Wichita, Kansas

A: Mercury is not a leftover core of a gas giant planet. Although extrasolar systems have revised the planet formation rulebook, we still think gas giants form far from their stars, about as far as Jupiter is from ours. Then, some planets migrate toward their suns. These planets are "hot Jupiters."

At Jupiter's distance, temperatures in the protoplanetary gas disk are low enough for ices to condense and for planetary cores to grow large enough to collect massive atmospheres before the gas dissipates — about 10 million years after the star forms. Mercury probably formed too hot and too late: Ices could not condense near Mercury, and the gas had disappeared by the time Mercury formed, more than 30 million years after the Sun.

It is also unlikely that Mercury formed farther from the Sun and migrated in, like a hot Jupiter. Migration of a gas giant from an orbit near Jupiter's to that of Mercury would prevent the other rocky planets and the asteroid belt from forming. Because of gravitational interactions, we might not expect to find rocky planets in systems with hot Jupiters.

Although not applicable to Mercury, certain processes can strip a hot Jupiter's atmosphere. There are indications that the transiting planets HD 209458b and WASP-12b are losing their atmospheres. Also, recent studies of the distribution of hot Jupiters' orbits show gaps in locations consistent with some of these planets' atmospheres evaporating. With the recent discovery of GJ 1214b, a gaseous planet larger than Earth but smaller than Neptune, we may already have found the remnant of an evaporated giant planet. Kepler and CoRoT, missions designed to find hundreds of extrasolar planets, may soon discover many more. **— Brian Jackson,** NASA's Goddard Space Flight Center, Greenbelt, Maryland

SORTING THROUGH FILTERS

Q: Is there a difference between visual and imaging filters?

— Kenny Bahmer, Champlin, Minnesota

A: You can use any filter for imaging, but not all work for visual observing. **Filters for visual use (called "broadband" filters) cut out a small fraction of light and increase the contrast of the target.** For example, they cut sky glow and enhance the contrast of nebulae.

Except in the case of color filters (like red, green, and blue), astroimagers don't use broadband filters because it's easier to remove byproducts like sky glow when they process their images. **Imagers tend to use "narrowband" filters.** Three common narrowband filters are Sulfur-II, Oxygen-III, and Hydrogen-alpha. **Such filters remove most light, allowing only the specified wavelengths to pass through to the camera.** So, these filters highlight specific emissions from nebulae. Later, during processing, imagers assign one of the three colors (red, green, or blue) to the data they captured through each narrowband filter. We label such images "false color" because the final product isn't a true RGB image. Why take such images? Because they show details in celestial objects that regular color images cannot. **— Michael E. Bakich,** Senior Editor

When observing, a broadband filter can enhance your view of some deep-sky objects, especially nebulae. Such filters increase the target's contrast. *Astronomy*: William Zuback

NOT A WAY TO TIME TRAVEL

Q: I've heard that wormholes could make time travel in the future possible. How realistic is this phenomenon? — Harold Kozak, Staten Island, New York

A: Wormholes are a theoretical idea for how "tunnels" of strong gravity — such as those produced inside a black hole — connect different regions of the universe. This idea is not just science fiction: Theoretical physicists have been interested in such things for some time. However, **wormholes would likely be unstable and would collapse on themselves the moment they were created.** So even aside from the practical issues, such as how to make a wormhole — a pretty enormous concern — **they don't seem all too promising for time travel. — Eliot Quataert,** University of California, Berkeley

A DIFFERENT END FOR HUBBLE?

Q: In the December 2009 issue of *Astronomy*, you explained why we couldn't bring the Hubble Space Telescope back to Earth. But can we attach it to the International Space Station? — Sylvain Robert, Trois-Rivières, Québec, Canada

A: The International Space Station (ISS) has pollutants that could damage the Hubble Space Telescope's mirror if it were docked to the ISS. Even if this weren't a concern, getting Hubble from one place to another requires a lot more energy than you might imagine. It's doable in terms of orbital mechanics, but it's risky and expensive.

While Hubble and the ISS are at different altitudes — about 350 miles (560 kilometers) and 200 miles (320 km), respectively — the issue is that they are in different orbital planes. Hubble's plane is inclined 28.5° to Earth's equator; the ISS is inclined 52° to the equator. The ISS's plane is at a much steeper inclination so that Russian space vehicles can easily get to it as it passes over Russia.

The best way to get Hubble to a higher inclination orbit to match the ISS would be with an ion rocket motor firing continuously for nearly 1 year. This would gently nudge Hubble into a steeper inclination.

We could then launch a propulsion bus (assuming one were developed for general spacecraft applications) and remotely attach it to the docking adapter on the telescope's aft shroud (Hubble's rear section, which holds the science instruments). The module would carry a few hundred pounds of xenon gas for fuel, an ion engine, and solar panels for electrical power to fire the motor. An ion engine ejects electrically charged particles at high velocity. The thrust is weak — equivalent to the force of a sheet of paper pressing down on your hand — but ion engines fire continuously so that acceleration builds up over time while using little propellant.

After Hubble was in the same plane as the ISS, we'd need a manned or robotic orbital transfer vehicle to climb to the telescope's new altitude orbit for servicing. It wouldn't work to lower Hubble to the ISS orbit for servicing because aerodynamic drag on Hubble would increase. **— Ray Villard,** Space Telescope Science Institute, Baltimore, Maryland

Visit www.Astronomy.com/toc to find out if we've found any multiple planet systems around other stars.

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187**. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

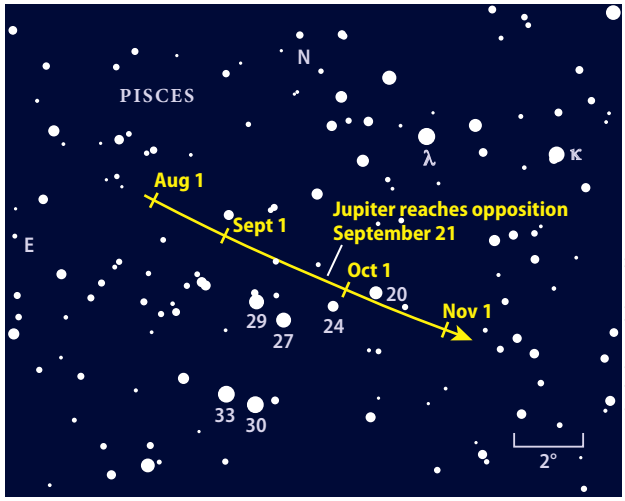
The king of planets reigns in September

With the giant planet bigger and brighter than it's been in more than a decade, let the cry go forth: It's Jupiter time! **by Michael E. Bakich**

Jupiter's opposition — the point in its orbit opposite the Sun as seen from Earth — arrives on the last day of summer in the Northern Hemisphere. Days and nights are equal in length, and the temperature is still comfortable. Now is the time to set up your telescope and observe Jupiter. While it's true that the planet will appear 14° higher at its next opposition, October 29, 2011, nights then will be colder than they are now. Besides, if you're like me, you won't want to wait another year to see the king of planets in all its glory.

When Jupiter reaches opposition September 21, it will appear bigger and more brilliant than at any time in 47 years. The planet will subtend an angle of 49.9" (close to its greatest possible size of 50.1"), and it will glare at magnitude –2.9. At that brightness, Jupiter will outshine all other starlike objects after Venus sets around 8 P.M. local daylight time.

For several months on either side of its opposition, Jupiter appears at the border of the constellations Aquarius the Water-bearer and Pisces the Fish. This region — bereft of bright stars — will provide a huge contrast to Jupiter's brilliance. In fact, the nearest 1st-magnitude star, Fomalhaut (Alpha [α] Piscis Austrini), lies more than 30° away.



Astronomy: Richard Talcott and Theo Cobb

Jupiter travels near the Pisces-Aquarius border throughout 2010. To find it around its opposition date September 21, simply look for the brightest point of light in the eastern evening sky.

For observers in mid-northern latitudes, the giant planet's location means it will climb only about halfway up the sky, still far from where the best views lie. At opposition, Jupiter's altitude maximizes at local midnight. An observer at latitude 40° north will then see the planet stand 48° above the southern horizon. In the Northern Hemisphere, for each degree of latitude south of 40° north, Jupiter will appear 1° higher; for each degree north of 40°, 1° lower.

Magnified views

Through a telescope, Jupiter will reveal more detail than any other celestial object except the Moon. Even a 2-inch scope will show the four Galilean satellites, named as such for their discoverer, Italian astronomer Galileo Galilei. The moons look like bright stars beside Jupiter and can form some unusual arrangements.

When you turn your gaze back to the planet, insert an eyepiece that provides a magnification around 100x, and the first details you'll notice will be a pair of dark stripes. These stripes — one above and one below the equator — are the North and South Equatorial Belts. Through larger telescopes and with higher magnifications, more belts and zones come into view.

At magnifications above 250x, Jupiter appears flattened. That's not an illusion. Rapid rotation and the fact that Jupiter is not solid make its equatorial diameter 5,600 miles (9,000 kilometers) greater than its polar diameter.

Rather than a quick look now and then, observe Jupiter over a series of nights. In addition to the changing positions of its moons, the planet's 9 hour and 55.5 minute rotation brings nearly all of its visible area into view in a single night.

The giant planet spins once in less than 10 hours, so you typically can see all of the planet's cloud features during one night. This sequence of five images shows 2 hours and 11 minutes of rotation. During that time, Io and its shadow transited Jupiter's disk. Damian Peach

Long-term observations may reveal individual features becoming more or less prominent and even disappearing for extended periods. As I write this, Jupiter's South Equatorial Belt has faded into invisibility. It may be back in time for opposition, but nobody knows for sure.

Forecast: cloudy

Jupiter's atmosphere divides into cloud bands of various colors oriented parallel to the planet's equator. Planetary observers call the light-colored bands "zones" and the darker ones "belts."

Jupiter's most famous atmospheric feature is the Great Red Spot (GRS), a high-pressure storm that lies 22° south of Jupiter's equator. The GRS has a north-south width of 8,700 miles (14,000 km) and a variable east-west width of 15,000 to 25,000 miles (24,000 to 40,000 km). The GRS is slowly shrinking, however, and is currently one-third shorter in length than it was in the 1890s.

The GRS shows frequent changes in color. It has varied from "brick red" during the 1960s to "pale pink" in the 1990s. Since 2000, the spot's hue has remained "light orange," although the GRS darkened slightly during 2002–03.

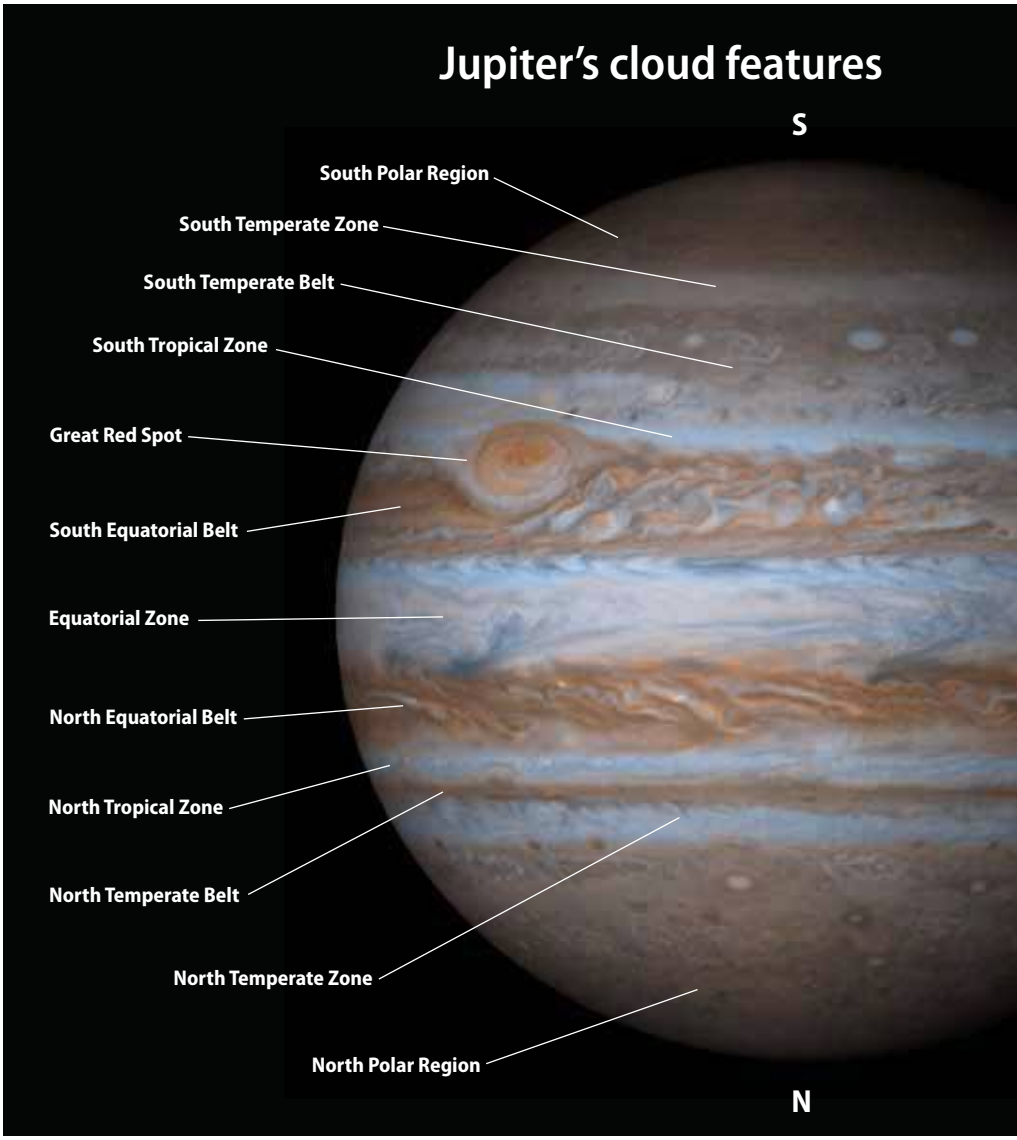
Zoom in on Galileo's satellites

Four events are possible involving Jupiter and its four large moons. You'll find them for each month in our "Path of the Planets" section (this month on page 37).

A satellite "eclipse" occurs when the satellite moves through Jupiter's shadow; an "occultation" when the satellite moves behind Jupiter; a "transit" when the moon moves in front of Jupiter; and a "shadow transit" when a moon's shadow moves across Jupiter's disk. Shadows look like small black dots through any scope.

After you observe Jupiter's four large moons enough to know which is which and how they move, kick your observing up a notch. Through a 10-inch or larger telescope and with good seeing, look for details on the Galilean satellites.

With high magnification (above 350x), you'll resolve distinct disks, especially during transits, when the moons' glare drops because Jupiter provides a lighter background. Try Ganymede, the largest moon, first. Look for light frost in its polar regions. Through even bigger scopes, you'll be able to discern each satellite's subtle color.



Because Jupiter rotates so quickly, its cloud bands divide into belts (darker colors) and zones (lighter colors). Use this guide to identify the planet's atmospheric features. NASA

Through a glass darkly

The best advice I have for Jupiter observers is to use color filters to bring out details you can't see otherwise. Such filters produce grayscale views that enhance the contrast between adjoining planetary features.

Manufacturers label filters by color and number. For enhanced views of Jupiter's dark reddish-brown belts, use a green (#58) or blue (#38A) filter. Blue also works best to sharpen any bright cloud features. A yellow (#12) filter will darken bluish features such as festoons, small regions that appear from time to time near the planet's equator.

Most observers employ red (#23 or #25A) filters to enhance white spots and ovals in the South Temperate Belt and Zone. Red filters also seem to work well on boosting the contrast of the northern and southern borders of the major belts.

Now is the time for Jupiter

As summer comes to a close in the Northern Hemisphere, Jupiter provides a brilliant target for new and seasoned planetary observers alike. So take this opportunity to see the giant planet at its best all year.

See a gallery of Jupiter images at www.Astronomy.com/toc.

Michael E. Bakich *is an* Astronomy *senior editor and longtime Jupiter observer.*

Astronomy magazine
2010 Star Products

Astronomy's first annual STAR PRODUCTS

Amateur astronomers take note: You might want to add these 35 products to your holiday wish list. **by Phil Harrington**

Each year, companies from around the world introduce telescopes, binoculars, and other gear for amateur astronomers. Some of the equipment that we can buy today was unimaginable just a few years ago. The 21st century is, indeed, a golden age for amateur astronomy.

Of course, that also made trying to decide which products to include in our first annual *Astronomy* Star Products all the more difficult. But after surveying the market, *Astronomy*'s staff and I selected 35 outstanding products. Some demonstrate innovative design. Others represent a breakthrough in technology. Still others offer an amazing bang for your buck. In this list, products appear in alphabetical order.

Astromist software

1

Astromist, one of the most versatile software applications for Palm-based computers, shrinks the full power of PC-based planetarium programs into pocket form. *Astromist* plots up to 2.5 million stars and more than 18,000 deep-sky objects, displaying them on charts that range from all-sky to eyepiece close-ups. It also shows the locations of the Moon, planets, and myriad comets. Beyond its display attributes, *Astromist* also lets users maneuver telescopes with Bluetooth or infrared control.

Astronomy Technologies AT8IN 8-inch f/4 imaging Newtonian

Fast-focal-ratio Newtonians are famous for their wide fields of view, making them perfect for photographing and viewing large-scale deep-sky objects. Astronomy Technologies has optimized the AT8IN for astroimaging, but the scope is just as adept for backyard viewing. For a relatively low price ($449), you get mirrors with 91 percent enhanced reflectivity, a tube optimized with internal baffles for improved image contrast, a built-in cooling fan, a 2" dual-speed Crayford focuser, and an 8x50 finder scope. Add a suitable mount and you have a versatile instrument that will take you into the depths of the universe in style.

2

Astronomy Technologies AT10RC 10-inch Ritchey-Chretien telescope

Ritchey-Chrétien Cassegrain reflectors are the most common professional telescopes, but some amateurs avoid them because of their high cost. Now, Astronomy Technologies breaks the price barrier with three affordable Ritchey-Chrétiens. The largest, the 10-inch f/8 AT10RC, is a superb photographic telescope. It offers premium features including quartz mirrors, a dual-speed Crayford-style focuser, dielectric mirror coatings, two dovetail mounting rails, and three built-in cooling fans.

3

Phil Harrington *is an* Astronomy *contributing editor and author of* Star Ware: The Amateur Astronomer's Guide to Choosing, Buying, and Using Telescopes and Accessories *(Wiley, 2007).*

Astronomy Technologies AT106LE 4.2-inch apochromatic refractor

One trend in amateur astronomy over the past decade has been the introduction of moderately priced apochromatic refractors. Among the finest in the 4-inch class is the 4.2-inch f/6.5 AT106LE from Astronomy Technologies. Outstanding optical performance characterizes this refractor thanks to its triplet objective. Inside, an FPL-53 ED (Extra-low Dispersion) glass element reduces false color while increasing contrast. In addition, the dual-speed 2" Crayford focuser, retractable dew shade, and aluminum storage case all create a first-rate telescope without the sticker shock.

Astronomy Technologies Voyager alt-azimuth mount

Astronomy Technologies' all-metal Voyager alt-azimuth mount is perfect for anyone who practices grab-and-go astronomy. Simply place your telescope's Vixen-style dovetail bar into the matching cradle on the Voyager's altitude axis, tighten the thumbscrew, and you are ready to observe. The mount's axes move smoothly in all directions, even when carrying telescopes weighing up to 20 pounds (9.1 kilograms). Adjustable slip clutches will let you aim the telescope anywhere in the sky and then manually track a celestial target with dual slow-motion controls.

AstroTrac TT320X-AG tracking mount

Guided wide-field astrophotography almost always means dragging out a heavy telescope mount, even if it's just for supporting a lightweight camera and lens — unless you use a compact tracking platform like the AstroTrac TT320X-AG. The 2.4-pound (1.1 kg) AstroTrac measures just 17 by 3 by 1.5 inches (432 by 76 by 38 millimeters) — small enough to tuck into a camera gadget bag. But once unfolded, mounted onto a camera tripod, and aligned with the celestial pole using the optional polar scope, the TT320X-AG will follow objects precisely. The manufacturer states that the tracking error is approximately 5 arcseconds peak-to-peak over a period of 5 minutes, ideal for most wide-field shots.

Baader 8–24mm Hyperion Clickstop Zoom Eyepiece

The saying "zoom is doom" applies to many low-end zoom eyepieces. In the past several years, however, a few companies have introduced premium-quality zoom eyepieces that produce exceptional images. One of the most recent is the Hyperion 8–24mm Zoom from Baader Planetarium in Germany. The seven-element Hyperion Zoom is continuously variable across the focal-length range but has click-stops at 8mm, 12mm, 16mm, 20mm, and 24mm. And like Baader's fixed-focal-length Hyperion eyepieces, the Zoom can accept an optional adapter for coupling any T-threaded camera or accessory to the eyepiece.

Canon EOS Rebel T1i DSLR camera

Digital single-lens reflex (DSLR) cameras have been a boon to astroimaging. And while many brands and models flood today's market, one of the best — in terms of both quality and value — is Canon's EOS Rebel T1i. Retailing for about $800, the T1i boasts a 15.1-megapixel CMOS sensor and a 3-inch Clear View liquid crystal display (LCD). The T1i can take high-definition video. You can also compose shots on the LCD monitor instead of just through the viewfinder like many other DSLRs. Put all these features together and you have a versatile astroimaging tool.

Celestron CGE Pro Mount

Without a sturdy mount, even the finest optical tube assembly will yield low-quality performance. But most heavy-duty mounts also come with a heavy-duty price. One of the best values is Celestron's CGE Pro German equatorial mount. The CGE Pro is light enough to easily transport, and it can carry up to a 90-pound (40.8 kg) payload. Plug it into a 12-volt DC power source and the onboard polar-alignment routine lets you accurately align the mount even if something is blocking the celestial pole from view. Once initialized, the CGE's go-to performance makes finding and tracking celestial objects easy tasks.

Celestron CGEM Computerized Mount

If you don't need as heavy duty a mount as the CGE Pro, then Celestron's CGEM go-to equatorial mount might be for you. With a capacity of 40 pounds (18.1 kg), it carries instruments up to 11 inches in aperture. And Celestron also designed the CGEM for portability using 12-volt power.

Celestron EdgeHD Series Schmidt-Cassegrain telescope

Celestron's new 8- to 14-inch EdgeHD telescopes improve the company's popular Schmidt-Cassegrain telescopes (SCTs) introduced 50 years ago. Described as "aplanatic," EdgeHD telescopes have a built-in field flattener/coma corrector in the instrument's baffle tube. This eliminates the "star bloat" that plagues photos taken through conventional SCTs. An improved focuser also reduces image shift, a common complaint among SCT owners.

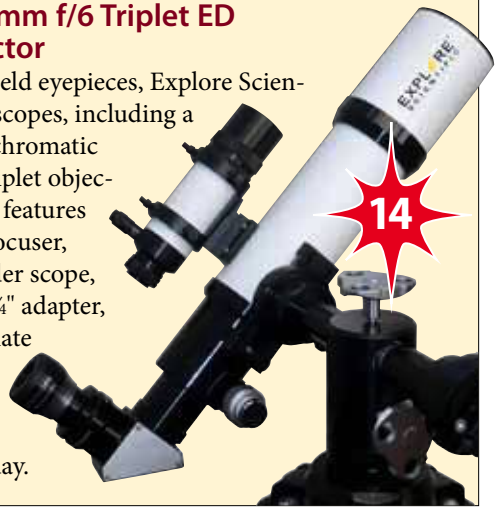
Celestron FirstScope

Just about every child has an innate interest in space. How can you turn that fascination into a lifelong love? Celestron's FirstScope might be just the ticket. At only $49.95, this 3-inch reflector comes with a standard 1¼" rack-and-pinion focuser, 20mm and 4mm eyepieces (which magnify 15x and 75x, respectively), and an amazingly steady tabletop mount. Weighing just 4.5 pounds (2 kg), the FirstScope can be carried by even 5- and 6-year-olds as they enjoy the Moon, bright planets, and dozens of deep-sky treasures. We recommend purchasing the separate accessory kit, which includes a finder scope, two eyepieces, a Moon filter, and a CD-ROM planetarium program, for about $20.

Explore Scientific 20mm 100° Series Nitrogen-Purged Waterproof Eyepiece

Explore Scientific may be a new company, but the 20mm eyepiece from its 100° Series is sure to increase the company's recognition. Like its 9mm and 14mm versions, the 20mm eyepiece features enhanced optical coatings inside a barrel that Explore Scientific seals and purges with nitrogen. The watertight barrel prevents internal fogging as well as contamination by dust and fungus.

Explore Scientific 80mm f/6 Triplet ED Apochromatic Refractor



In addition to their wide-field eyepieces, Explore Scientific offers several fine telescopes, including a 3.15-inch (80mm) f/6 apochromatic refractor. Built around a triplet objective, the lightweight ED 80 features a 2" dual-speed Crayford focuser, an 8x50 correct-image finder scope, a 2" star diagonal with a 1¼" adapter, and a dovetail mounting plate to secure the scope onto many of the most popular alt-azimuth and German equatorial mounts sold today.

Focus-Mask Bahtinov mask focusing aid

Those readers who have never tried astrophotography may be surprised to learn that achieving sharp focus is one of the most difficult things to do. Rather than rely solely on trial and error, photographers in the know use special focusing tools, including various masks placed over the front of their telescopes. One of the most ingenious is the Bahtinov mask sold by Focus-Mask. To use, aim toward a reasonably bright star, take a 3- to 5-second exposure, and then examine the three diffraction spikes. Adjust focus, take another picture, and again examine the diffraction spikes. Tweak the focus again and take subsequent exposures until the middle diffraction spike lies directly between the other two.

Garrett Optical Signature 20x110 HD-WP Binoculars

Two of the best buys in giant astro binoculars today are the 20x110 monster (shown here) and its higher magnification 28x110 cousin. These units make up Garrett Optical's Signature Line. Both boast 4.3-inch objectives for wonderfully expansive views of the night sky. The 20x100 squeezes 2.7° of sky into a single field of view, making it ideal for such striking targets as the Pleiades (M45) and the Double Cluster (NGC 869 and NGC 884). And although the eyepieces are not removable, both Signature binoculars can have standard 1¼" astronomical filters threaded into each eyepiece.

HOTECH SCA Laser Collimator

While laser collimators are useful tools for aligning a telescope's optics, one of their inherent weaknesses is that the collimator may not be square to, or centered in, the focuser. No matter how precisely the machining of the collimator's barrel, a small gap may exist between it and the focuser's drawtube. HOTECH's laser collimators come with the company's Self-Centering Adapter (SCA), which eliminates the problem. When the adapter sits in a focuser, rubber compression rings expand evenly against the drawtube, centering the collimator. It's a clever idea that works well.

iOptron MiniTower go-to mount

Weighing just 9 pounds (4 kg), the iOptron MiniTower is a self-contained go-to mount that sets up in minutes. Carry it outside in its hard case, attach it to the matching stainless steel tripod, and power it on. After a quick alignment routine, your telescope is ready to "go-to" any of the 130,000 objects programmed into the included SmartStar hand controller. Despite its small size, the MiniTower can hold up to 25 pounds (11.3 kg), making it perfect for refractors and catadioptric telescopes.

Kendrick Astro Instruments Stargate Observer Tent

Measuring 10 feet wide by 15 feet long and 6.5 feet high at the center (3 by 4.6 by 2 meters), the Kendrick Stargate Observer Tent is a new and improved incarnation of the company's Observatory Tent first introduced more than 10 years ago. Like the original, this clever design has two rooms separated by a polyester wall. Telescopes get the roomier side (10 by 9 feet [3m by 2.8m]) while bleary-eyed astronomers can sleep the day away in the smaller area (10 by 6 feet [3m by 1.8m]). Once you assemble the tent, bring the telescope inside and unzip the 6-foot-wide (1.8m) observing flap to enjoy the sky. When the night is done, simply close the flap, cover your telescope, and head to the next room for a well-deserved sleep.

Meade LS-6 go-to telescope

Incorporating the industry's most advanced go-to system — which integrates GPS satellites, internal leveling sensors, a magnetic north compass, and a built-in CCD imager — Meade's LS-6 offers truly hands-free sky alignment. Simply place the scope on its tripod, flip the switch, and sit back. Within minutes, the telescope is ready not only to take you to thousands of objects in the current sky, but also to tell you all about them. Whether you choose the Schmidt-Cassegrain or Advanced Coma-Free optical design, the LS-6 is both telescope and teacher rolled into one.

Orion BT100 Binocular Telescope

Orion's BT100 Binocular Telescope offers the best of both worlds. On one hand, you have a 4-inch refractor that accepts standard 1¼" eyepieces. On the other, you get the benefit of using both eyes for viewing. The BT100 features an all-metal body, fully multicoated achromatic objective lenses, Porro prisms made of BaK-4 glass, and removable eyepieces. Mount on a heavy-duty tripod, pop the included 24x eyepieces (or any matched pair of standard eyepieces) into the integrated 90° prism assemblies, and get ready to experience the beauty of the universe through two eyes.

Orion Parsec 8300C Astronomical Imaging Camera

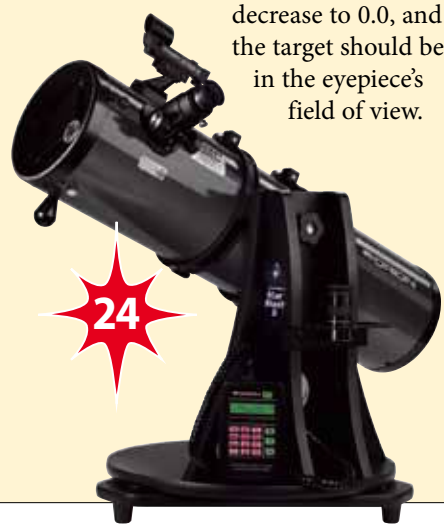
Built around Kodak's 8.3-megapixel KAF-8300 CCD sensor, Orion Telescope's Parsec 8300C is one of today's most advanced one-shot color astroimagers. Each of those 8.3 million pixels measures 5.4 x 5.4 microns, which translates to high-quality image resolution. At the same time, dual-stage cooling reduces thermal noise. The imager is compatible with Windows XP and later operating systems, and it connects to your computer's USB 2.0 port with the included cable. Power to the Parsec 8300C is via the 12-volt DC power cable that plugs into a car accessory jack.

Orion SkyQuest XX14i IntelliScope Truss Dobsonian

We tested Orion's XX12i shortly after the company introduced it in 2009. Building on its success, Orion recently unveiled the 14-inch f/4.6 XX14i. Like the 12-inch model, the XX14i features a truss-tube optical assembly perched atop a Dobsonian base outfitted with the IntelliScope object-locator system. The telescope is a joy to use thanks to important refinements, such as a smooth two-speed Crayford-style focuser, bearings made from Teflon and Ebony-Star laminate, and an 8x50 finder scope. The XX14i offers a large aperture at a remarkably low price.

Orion StarBlast 6i IntelliScope Reflector

When Orion introduced the 6-inch f/5 StarBlast 6 a couple of years ago, we gave it high marks. Now, Orion is back with a new, sophisticated version it calls the StarBlast 6i. The "i" stands for IntelliScope, the company's successful computerized locator system. After selecting one of the sky objects in the computer's memory, two directional guide arrows with numbers appear on the hand controller's illuminated LCD screen. Push the telescope in the direction of the arrows until both numbers decrease to 0.0, and the target should be in the eyepiece's field of view.



Orion StarShoot Solitaire AutoGuider

You own a digital SLR camera and a telescope mount equipped to accept an SBIG ST-4-compatible autoguider, and you want to try your hand at deep-sky photography. But you don't want to drag a computer outside to run the autoguider. Well then, Orion's new StarShoot Solitaire AutoGuider is for you. The StarShoot Solitaire is completely self-contained. Plug it into a standard 1¼" focuser, connect it to a 12-volt battery, and you're ready to shoot. A small hand-held control box operates the Solitaire.

Santa Barbara Instrument Group SG-4 autoguider

The ST-4 autoguider, a small CCD camera introduced more than 15 years ago by SBIG, forever changed astrophotography by eliminating the backbreaking chore of having to guide and check a telescope's tracking rate manually. Last year, SBIG unveiled their latest autoguider, the SG-4. Unlike the ST-4, which you must connect to a computer to use, the SG-4 is a stand-alone unit. The initial calibration to a telescope mount requires a computer, but after that, the SG-4 will work autonomously with the touch of a button. This makes it perfect for any astrophotographer who wants to keep gear to a minimum when traveling to remote sites.

Santa Barbara Instrument Group ST-8300C High Resolution CCD Camera

SBIG continues its role as innovator with its ST-8300C high-resolution imager. Featuring Kodak's KAF-8300C, 8.3-megapixel, full-frame CCD chip, the ST-8300C offers the convenience of single-shot color imaging. The imager's body, machined from solid aluminum and then hard anodized for durability, accepts both C-mount and standard 35mm Nikon camera lenses. The ST-8300C includes a 15-foot (4.6m) USB 2.0 cable for fast downloads and works with current Windows and Mac operating systems. It also comes with an AC power supply, as well as a 12-volt DC power cable.

Sky-Watcher Pro 120ED APO Refractor

The largest apochromatic refractor in this year's Star Products selection is the 4.7-inch f/7.5 Sky-Watcher Pro 120ED. The attractive black tube and white focuser and dew shield create a handsome instrument. But telescopes are not to look at; they are to look through, and the Pro 120ED does not disappoint. Sharp, high-contrast images free of spurious color do not hint at the telescope's surprisingly low price. Add a dual-speed 2" focuser, 20mm and 5mm Plössl eyepieces, a 9x50 finder, tube rings, a standard dovetail mounting bar, and a hard-side carrying case, and you have one of the best bargains in the economy APO market today.

Sky-Watcher 12-inch Collapsible Dobsonian reflecting telescope

When it comes to deep-sky observing, size matters: Big optics = bright images. But in this light-polluted world, how can urban or suburban dwellers transport large telescopes from home to field? The Sky-Watcher 12-inch Collapsible Dobsonian may be their salvation. Rather than rely on traditional truss tubes, which you have to piece together every time you set up the telescope, the SW-12 uses a unique three-pole design that allows the instrument's upper and lower cells to collapse together with the support poles still in place. The simplicity and elegance of this telescoping telescope makes assembly quick and painless. Collimation holds well even after several setups and tear downs.

Software Bisque *TheSky X* planetarium software

Software Bisque's *TheSky X*, the latest version of the popular software package, is one of the most advanced planetarium programs sold today. Available in three editions for Windows or Mac OS X — Student, Serious Astronomer, and Professional — *TheSky X* shows the sky on any date in the past, present, or future. From the comfort of your desk or armchair, you can learn the constellations, watch the planets move centuries at a time, witness solar and lunar eclipses, explore the depths of deep space, and plan your next observing session. *TheSky X* can control your go-to telescope if you choose or produce detailed charts to use at the eyepiece.

Starmap software

Programmers are introducing iPhone and iPod Touch applications at a fast and furious rate these days. One of the coolest for amateur astronomers is called *Starmap*. For $11.99, you get a full-featured planetarium program that will display up to 2.5 million stars, as well as the Sun, the Moon, planets, and thousands of deep-sky objects visible from anywhere on Earth. Users may either input their selected time, date, and location manually or let their iPhone's GPS feature do it for them. *Starmap*, from France, comes in eight different languages.

Starry Night Pro Plus 6.3 planetarium software

One of today's most popular planetarium programs, *Starry Night* comes in several levels. The Pro Plus level has a feature not found in the other versions: a photographic mosaic of the entire sky. The all-sky image weaves together some 20,000 images to create a seamless tapestry that captures stars to magnitude 15. Beyond this, *Starry Night Pro Plus 6.3* will take you on animated trips between the planets and let you view millions of stars and deep-sky objects. *Starry Night Pro Plus 6.3* can control most popular go-to mounts, as well as process images using a plug-in for *Starry Night* and *MaxIm DL* software (sold separately).

Tele Vue 21mm Ethos eyepiece

The first view you have through a Tele Vue Ethos, regardless of the focal length, will be one of those astronomical moments of a lifetime. Capitalizing on the company's success with earlier focal lengths, Tele Vue recently introduced a 10mm Ethos, as well as the 21mm model we single out here. Like the others, the 21mm Ethos offers an incredible 100° apparent field of view. One look and you're hooked for life. For the true connoisseur of fine eyepieces, the 21mm Ethos offers panoramic views of large-scale objects in unprecedented crispness and clarity.

TMB Optical 9mm 100° 1¼"/2" Eyepiece

An eyepiece with a 100° apparent field of view that fits into a standard 1¼" focuser? That's exactly what TMB Optical's 9mm 100° eyepiece does. Leave the 2" skirt in place if your telescope has a 2" focuser, or unscrew it to reveal a hidden 1¼" barrel. That lets the TMB 9mm 100° fit nearly all telescopes both large and small, making this one of the most versatile wide-field eyepieces sold today.

TMB Optical TMB-92L refractor

Whether it's a weekend camping trip or traveling to see a total solar eclipse, many amateurs enjoy astronomy on the go. To pull it off, however, you need a telescope that is small and lightweight, yet sharp enough to deliver the goods when you finally get to your destination. TMB Optical's TMB-92L (the L stands for "light") apochromatic refractor is just such a scope. Inside, the heart of this little powerhouse — a 3.6-inch f/5.5 triple objective — is optically superb, while the dual-speed 2" Crayford focuser brings everything into razor-sharp view.

Astronomy's Star Products

Astronomy magazine 2010 Star Products

#	COMPANY	PRODUCT	PRICE	WEBSITE
1	Astromist	*Astromist*	$39	www.astromist.com
2	Astronomy Technologies	AT8IN	$449	www.astronomytechnologies.com
3	Astronomy Technologies	AT10RC	$2,695	www.astronomytechnologies.com
4	Astronomy Technologies	AT106LE	$1,495	www.astronomytechnologies.com
5	Astronomy Technologies	Voyager	$299	www.astronomytechnologies.com
6	AstroTrac	TT320X-AG	$525	www.astrotrac.com
7	Baader Planetarium	8–24mm Hyperion Clickstop Zoom Eyepiece	$198	www.baader-planetarium.com
8	Canon	EOS Rebel T1i	$799.99	www.canon.com
9	Celestron	CGE Pro Mount	$4,999	www.celestron.com
10	Celestron	CGEM Computerized Mount	$1,399	www.celestron.com
11	Celestron	EdgeHD Series 8- to 14-inch Optical Tube Assembly	$1,299 to $5,799	www.celestron.com
12	Celestron	FirstScope	$49.95	www.celestron.com
13	Explore Scientific	20mm 100° Series Eyepiece	$599	www.explorescientific.com
14	Explore Scientific	80mm f/6 Triplet ED Apochromatic Refractor	$799	www.explorescientific.com
15	Focus-Mask	Bahtinov mask	$18.95–54.95	www.focus-mask.com
16	Garrett Optical	Signature 20x110 HD-WP Binoculars	$649.95	www.garrettoptical.com
17	HOTECH	SCA Laser Collimator	$89.95	www.hotechusa.com
18	iOptron Corporation	MiniTower	$799	www.ioptron.com
19	Kendrick Astro Instruments	Stargate Observer Tent	$795 Can.	www.kendrickastro.com
20	Meade	LS-6	$1,399–1,499	www.meade.com
21	Orion Telescopes and Binoculars	BT100 Binocular Telescope	$1,099.95	www.oriontelescopes.com
22	Orion Telescopes and Binoculars	Parsec 8300C	$1,999.95	www.oriontelescopes.com
23	Orion Telescopes and Binoculars	SkyQuest XX14i	$1,799.95	www.oriontelescopes.com
24	Orion Telescopes and Binoculars	StarBlast 6i	$399.95	www.oriontelescopes.com
25	Orion Telescopes and Binoculars	StarShoot Solitaire AutoGuider	$499.95	www.oriontelescopes.com
26	Santa Barbara Instrument Group	SG-4 autoguider	$995	www.sbig.com
27	Santa Barbara Instrument Group	ST-8300C High Resolution CCD Camera	$1,995	www.sbig.com
28	Sky-Watcher	Pro 120ED APO Refractor	$1,695	www.skywatcherusa.com
29	Sky-Watcher	12-inch Collapsible Dobsonian	$995	www.skywatcherusa.com
30	Software Bisque	*TheSky X*	$60–329	www.bisque.com
31	Starmap	*Starmap*	$11.99	www.star-map.fr
32	Starry Night	*Starry Night Pro Plus 6.3*	$249.95	www.starrynight.com
33	Tele Vue	21mm Ethos	$815	www.televue.com
34	TMB Optical	9mm 100° 1¼"/2" Eyepiece	$299	www.tmboptical.com
35	TMB Optical	TMB-92L	$1,495	www.tmboptical.com

Astronomical adventure

A night at Granite Gap

Astronomy, geology, history, and much more are converging in a big way in southwestern New Mexico. And amateur astronomers will benefit the most. **by Michael E. Bakich**

Granite Gap. To some, the name conjures up images of the Old West: ghost towns, gunfights, and prospectors hunting for gold. To others, it speaks of the region's geology: vistas dotted with granite and limestone ridges, and miners extracting copper and silver.

But to developer Gene Turner, Granite Gap represents a way to expand his love of astronomy to a wider audience. Turner sees huge potential in the area, and investors are already coming onboard.

His plans include a large plot of real estate under a pristine sky subdivided and offered to amateur astronomers at low cost; a preserve featuring numerous species of birds and other wildlife, nature trails, and fishing; and two world-class science facilities — a planetarium and a mineral museum. Judging by Turner's previous successes, in a few years all this and more will exist at a formerly lonely spot in southwestern New Mexico called Granite Gap.

Unlike rentals, astronomy vacation spots, or online observing, this development will offer amateur astronomers their own land under a pristine sky. Science attractions at the same site will entertain the whole family. And access is easy — you won't have to travel endless miles on dirt roads to reach it.

The ideal location

Granite Gap sits 8 miles (13 kilometers) south of Interstate 10 on New Mexico Highway 80. Easy access from I-10 was an important consideration for Turner as he planned this region's future. This setting lies at an altitude of 4,700 feet (1,433 meters), only 4 miles (6.4 km) north of his other development, Rancho Hidalgo.

Average winter temperatures range from lows around freezing to highs around 65° F (18° C). The altitude moderates the Desert Southwest's summer temperatures, which vary there from around 60° F (16° C) at night to as much as 95° F (35° C) during the day. Best of all, Granite Gap enjoys about 350 days of sunshine per year.

Turner already has launched two successful astronomy communities in the area. The first, Arizona Sky Village (ASV), near Portal, Arizona, contains 250 fully developed acres. The majority of the houses there feature personal observatories. As the available land at ASV dwindled, Turner began acquiring land across the state line in New Mexico.

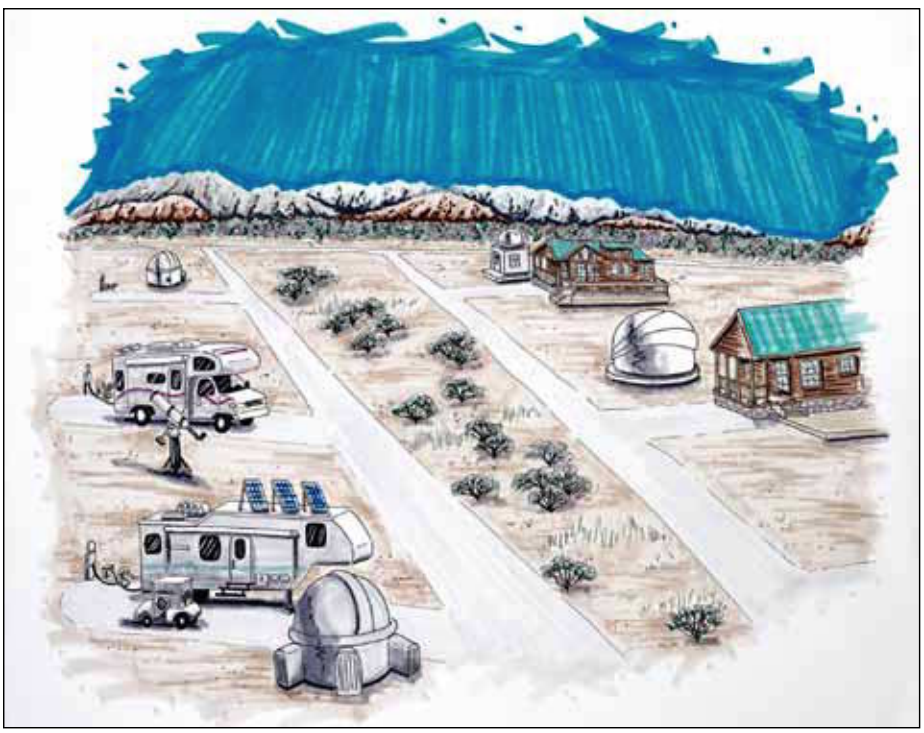
His second community is the result. Rancho Hidalgo Astronomy and Equestrian Village (RH) lies near Animas, New Mexico. It contains 7,000 acres, including an adjacent lease. Of this total, Turner set aside 300 acres for growing alfalfa and 100 acres for chili peppers along with 5,000 acres for raising cattle and equestrian needs. The remaining 1,600 acres will accommodate residential dwellings.

RH is also the location of *Astronomy* magazine's observatory. Turner constructed that facility in 2009. Several editors already have traveled there to observe from the site.

Water is the key

The climate in this region qualifies as "desert," which translates to an average rainfall of less than 10 inches (250 millimeters) per year. Last year, only 3 inches (76mm) of rain fell.

As it turns out, growing crops and raising cattle are still possible because



One of Granite Gap's future developments will be an RV park. Owner Gene Turner dubbed this area the "Yearlong Star Party." Amateur astronomers can construct permanent observatories, purchase time in well-apportioned cabins, or just park their campers for short-term observing sessions. A fully stocked 40-acre lake sits just south of the park. Holley Y. Bakich

Michael E. Bakich, *an* Astronomy *senior editor, is always searching for darker skies.*

The California Nebula (NGC 1499) in the constellation Perseus is a celestial wonder the photographer captured with an 80-minute exposure through a 3-inch telescope at Arizona Sky Village, which lies just across the New Mexico state line in Arizona. The author saw this object from Granite Gap with no optical aid other than a nebula filter. Amateur astronomers will appreciate the atmospheric steadiness above the site. Jack Newton

Turner's New Mexico development sits on a huge aquifer (an underground layer of water-bearing material).

Snow melt from the Peloncillo Mountains to the south replenishes the aquifer. During 2009, RH was able to pump 3,000 gallons of water per minute for nearly 9 months with no measurable depletion of the aquifer.

The third act begins

In April, RH received approval from the Hidalgo County Commission for its final plat (a scale drawing showing how the developer will divide the land). This was the final step before building could occur. Several lot owners then expressed interest in beginning construction, and Turner started building the first house in May.

As the development of RH progresses, Turner is beginning to focus on Granite Gap. He purchased 700 acres earlier this year and also negotiated a lease for an adjoining 3,000 acres with the Bureau of Land Management. Then the wheels started turning. Astronomy still ranked first and foremost in Turner's mind, so what possibilities existed?

Specifically, he considered the question, "How can I share this superb venue with amateur astronomers from around the world?" One way was to do it through the Internet, so he set up a large, descriptive website at www.granitegap.com. But Turner always had a hands-on approach to observing, and his astronomy friends are of a similar mindset.

A 365-day star party

So, of the land he acquired at Granite Gap, Turner set aside 300 acres. His company is now developing the area into a recreational vehicle (RV) park he has dubbed the "Yearlong Star Party."

Amateur astronomers have two options regarding the land at the park. A one-time fee of $2,500 will lease a one-third acre plot for 99 years. Once the land is yours, you can build a small observatory there, erect a telescope pier, or park an RV at the site.

The second option starts at $12,500. Amateur astronomers who pay this amount once will have access to a well-apportioned 400-square-foot (37.2 square meters) cabin for 6 months each year. The 6-month span need not be continuous. You can occupy a cabin at your discretion throughout the year. Both cabins and plots at the RV park will feature electricity, water, septic facilities, and high-speed Internet.

The RV park offers a terrific opportunity for observers and imagers who struggle to find a high-quality observing site. I know several people who already are chomping at the bit to buy their own land at Granite Gap, including me. I wondered if Turner's corporation will offer financing. A quick call confirmed that, indeed, he plans to make financing available for individual purchases.

To ensure amateur astronomy will flourish, light-pollution rules will be in effect year-round. Any external cabin light must be a shielded fixture. And cars and RVs cannot enter after dark. If they arrive during "imaging time," they can park at a designated area next to the RV park until morning.

How good is the sky at the Gap?

During my last visit to Rancho Hidalgo in January 2010, one of my priorities was to observe under Granite Gap's sky. I rated both the seeing and the transparency as superb. Seeing is a measure of the atmosphere's steadiness above any location. The best astroimagers produce high-quality shots because they enjoy great seeing from their observing sites.

Observers judge transparency in two ways: by measuring a site's limiting visual magnitude and by counting deep-sky objects they can see without optical aid. The first night at Granite Gap, I estimated the limiting magnitude at 7.4, about as dark as I've ever experienced.

I then made a quick tally of the deep-sky objects I could see without optical aid. A dozen of Messier's open clusters appeared immediately. Among the

This high-desert site at the south end of the Granite Gap development marks the future location of Shoemaker Discovery Park. From here, visitors will explore a mineral- and meteorite-laden crater and participate in model rocket launches. Granite Gap sits 4,700 feet (1,433 meters) above sea level and enjoys sunshine an average of 350 days each year. Gene Turner

faintest were magnitude 6.2 M93 in Puppis and magnitude 6.4 M38 in Auriga.

Using only a nebula filter, I also spotted the California Nebula (NGC 1499) in Perseus and the Rosette Nebula (NGC 2237–9) in Monoceros. The list goes on. In summation, I rated this site as one of the finest I've ever visited. In terms of sky darkness, seeing, and transparency, it is world-class.

The Preserve at Granite Gap

As fantastic as astronomy is at ASV, RH, and soon Granite Gap, Turner's plans include much more. He has set aside a wildlife refuge complete with a 40-acre lake, which his company is now creating.

Granite Gap will initially feature 10 miles (16 km) of hiking trails. Wildlife, although sometimes difficult to spot in the desert, abounds here. In January, two ornithologists completed a survey of birds in the Granite Gap area. In 3 weeks, they spotted more than 100 species.

In addition to foot trails, visitors also will be able to take longer excursions on horseback. Atop proud and beautiful animals, riders will learn about the geology of the Southwest, cowboy history, mining, and more. Some trips will even lead to former Native American habitats.

Shoemaker Discovery Park

A park at the south end of the Granite Gap development will house a workshop next to an open field. This will be the venue where students and hobbyists construct and launch model rockets.

Nearby, visitors will be able to dig for regional minerals and meteorites in a large pit simulating an impact crater. In doing so, they will learn how minerals develop and how craters form on Earth and on other solar system bodies.

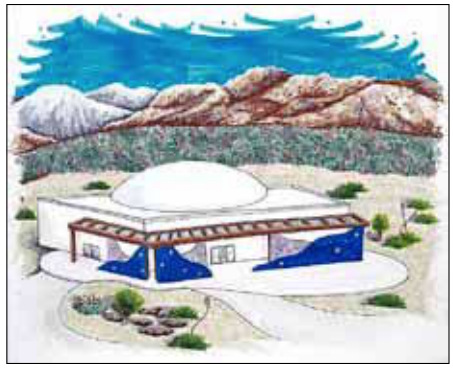
Shoemaker Discovery Park honors planetary scientist Eugene Shoemaker (1928–1997), a pioneer in the field of astrogeology. Shoemaker, his wife Carolyn, and *Astronomy* columnist David H. Levy discovered Comet Shoemaker-Levy 9, which struck Jupiter in 1994.

Focus on education

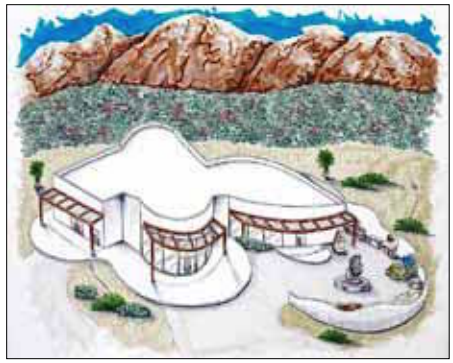
Early in the planning phase for Granite Gap, Turner recognized the need for a focal point from which his goal of science education could originate. Two buildings now in the design phase — a planetarium/science center and a mineral museum — will fulfill this objective.

Most people think of a planetarium as a place for people to experience astronomy. While that's true, every planetarium also houses a multimedia theater fully capable of presenting programs on a wide variety of subjects. So the planetarium will feature, for example, shows about solar power, Southwestern desert animals, meteorology, and more, in addition to ones dealing with the origin of the universe, what's up in the spring sky, and why Pluto should still be a planet.

The mineral museum is the other tine in Turner's two-pronged educational thrust. In addition to housing one of the country's finest mineral collections, it will feature state-of-the-art interactive exhibits, a fully equipped demonstration laboratory, and personalized tours. Galleries will highlight the history of mining, minerals of New Mexico and Arizona, and a meteorite gallery.



The planetarium at Granite Gap will feature daytime programs for the public and school groups on a variety of scientific and regional subjects. In addition, it will house exhibits on astronomy and space science as well as a research library. Holley Y. Bakich



The mineral museum at Granite Gap will have galleries focusing on the main collection, local mineralogy, and the history of mining. Traveling exhibits will be housed in a 3,000-square-foot (279 square meters) gallery. Outside, a mineral garden will display giant specimens. Holley Y. Bakich

In addition, visitors heading to and from the Tucson Gem and Mineral Show that occurs each February will find special exhibits in the mineral museum, special programs in the planetarium, and special deals in the huge gift shop.

These two facilities will welcome thousands of visitors annually. Many will be travelers drawn by an unexpected group of attractions midway between Tucson and El Paso. Others will be teachers and students on all-day field trips from the region's schools.

But I think the happiest guests will be amateur astronomers who have fled their cold and cloudy home towns for Granite Gap. There, under the darkest, steadiest skies, they will enjoy an observing opportunity that few get in a lifetime.

Read previous stories about the other developments in this area at www.Astronomy.com/toc.

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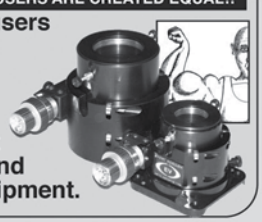

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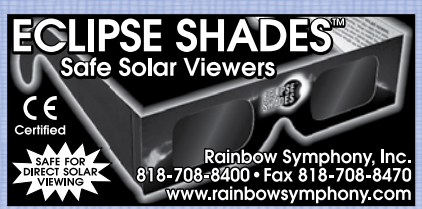
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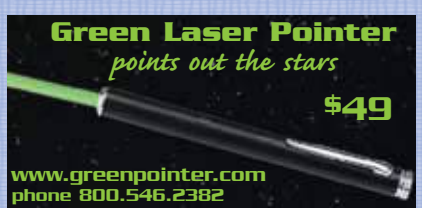
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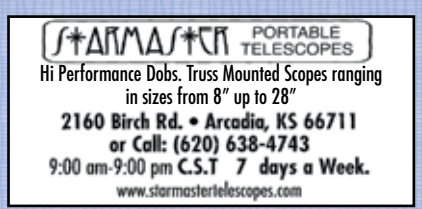
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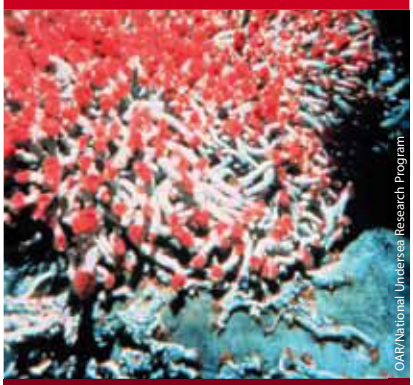
in the October issue



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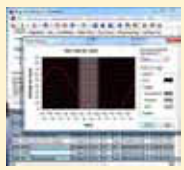

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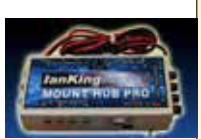

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The Cosmic Grid

All things high, low, weird, and wonderful in astronomy and space science. **by Bill Andrews**

WEIRD

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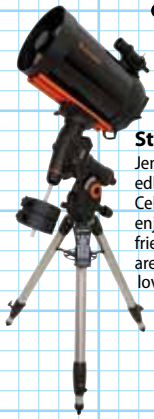
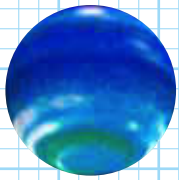
Singin' Spitzer
"Spitzer Space Telescope: The Musical" hits the stage, featuring a catchy jingle about the telescope and infrared light. Can't wait for "Hubble: On Ice"!

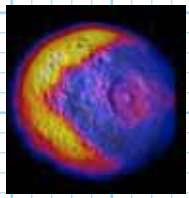


Stars seeing stars
Jennifer Aniston reportedly buys herself a $3,000 Celestron scope and enjoys showing it off to friends. If the rumors are true, Jennifer, we'd love some pictures!

To boldly govern
A popular Facebook group aims to "Help nominate William Shatner for Governor General of Canada." The speeches alone would be worth it.

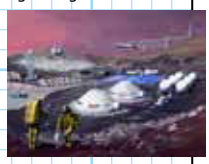
Planetary clash
Neptune may have eaten an ancient rocky planet and stolen its moon, but astronomers are unsure whether it also stole the planet's lunch money.





Pac-Moon
Saturn's moon Mimas shows off its '80s spirit in a recent Cassini infrared image.

Marsland
Developers hope to create a theme park that simulates a settlement on Mars, which is sadly about as close as anyone my age will get to one.

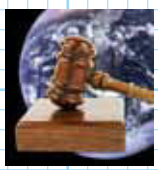


Cosmic car crashes?
A University of Nebraska-Lincoln researcher suggests some of Toyota's safety problems are due to cosmic rays. Suddenly classes in space law don't sound so crazy.

Noisome news
An exasperated Brian Cox tweets: "For the very last time — the [Large Hadron Collider] story is a pile of merde, as we say at CERN. Scheduled maintenance stops are not bloody news!" Of course, calling it "bloody news" makes even more cameras appear.

HOT

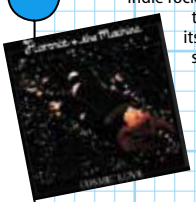
Space cases
A British university starts teaching outer space law. "WHEREAS, Space is a frontier; and WHEREAS, It may be considered the final one; therefore, be it RESOLVED, These are the voyages . . ."



Extinction explication
A March issue of *Science* confirms that an asteroid caused the dinosaurs' extinction about 65 million years ago. Anyone old enough to remember when it was a giant mystery breathes a sigh of relief.

NOT

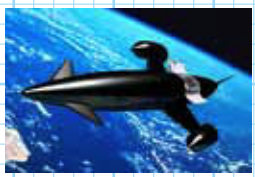
Spacey song
Indie rock band Florence + the Machine does its part to promote space enthusiasm with the "Cosmic Love" single and tour, following in David Bowie's odd footsteps.



Vampire science
Chris Weitz, director of *The Twilight Saga: New Moon*, says he specifically wanted to make the Moon look as accurate as possible. Because I'd hate for a movie about vampires and werewolves to get the science wrong.

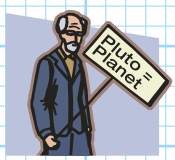
Martian tutor
In an unusual twist, the Mars rovers were able to lift something back on Earth: the math and science scores of Texas students studying them.

Fishy future
SKYLON, a reusable spaceplane in development at Reaction Engines, promises to usher in a new age of space travel, all while looking vaguely harpoon-like.



Marsly possessions
The Planetary Society blogs excitedly that "Phobos has gravity!" Well, I guess in this economy, you just can't assume what anyone has.

Head in the clouds
The United Kingdom Space Agency launches in March with little fanfare and few details about the future. Some might say they're following NASA's lead.



Plutonian rights
Seattle-based Greenwood Space Travel Supply Co. stages its third annual "Pluto IS a Planet" protest. Unfortunately, it's about as likely to effect change as a political rally.

Wicked warp speed
Space.com runs a story explaining why any kind of warp speed "will kill you." Dang it, science, can't you ever let us have any fun?

Taking up space
New York City makes a bid to house one of the space shuttles after their imminent grounding. Plans to convert the cargo bay into 3 studio apartments are presumably imminent as well.

Race to the middle
Russia stops its space tourism industry just as NASA gears up for its last few shuttle flights, signaling a new phase of the "stop going to space" race.

Love on the launchpad
China's human spaceflight program requires women (but not men) to be married before becoming astronauts. Looks like China won't be leading human rights in space either.

PREDICTABLE

PHOTOGRAPHS: Martin Aircraft (But what about hovercars?); NASA/JPL-Caltech (Singin' Spitzer); Celestron (Stars Seeing Stars); Jerry Avenaim (To boldly govern); Photos.com, NASA (Space cases); L. Sromovsky and P. Fry (University of Wisconsin- Madison) et al./NASA (Planetary clash); NASA/JPL/GSFC/SWRI/SSI (Pac-Moon); NASA (Marsland); M. DeBord, R. Ramaty, and B. Kozlovsky (GSFC)/R. Lingenfelter (UCSD)/NASA (Cosmic car crashes?); European Organization for Nuclear Research (Noisome news); NASA/Lewis Research Center/Quentin Schwinn (Wicked warp speed); NASA (Taking up space); © 2010 Jupiterimages Corporation (Plutonian rights); NASA (Race to the middle); © 2010 Jupiterimages Corporation (Love on the launchpad); Florence + the Machine (Spacey song); NASA/JPL/USGS (Vampire science); NASA/JPL (Martian tutor); Reaction Engines Ltd/Adrian Mann (Fishy future); G. Neukum (FU Berlin) et al./Mars Express/DLR/ESA (Marsly possessions)

ImagingtheCosmos

by Tony Hallas

Editor's note: Welcome to the first column by world-renowned astroimager Tony Hallas. He has been shooting the sky for more than 3 decades and has produced some of the finest images by an amateur astronomer. By following his advice, you will become a better astroimager.

Getting clean images

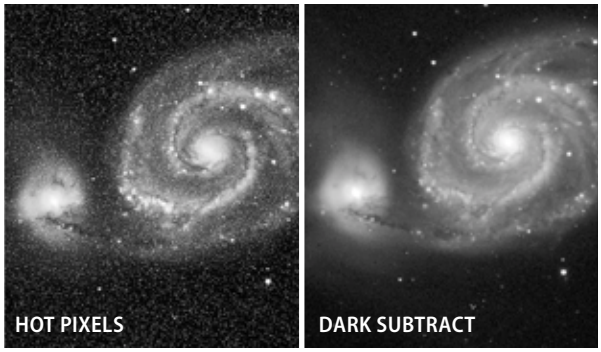
High-quality astroimaging involves using correct post-processing techniques.

By now, the charge-coupled device (CCD) camera is well-known to many of *Astronomy*'s readers who take celestial images. But there are still holdouts who prefer the DSLR for its low cost and ease of use. Also, some new imagers aren't sure if a CCD camera is the right choice. To help you understand what's involved if you choose a CCD camera, and to lay the groundwork for future columns that deal with processing CCD data into stunning images, I dedicate this column to CCD basics.

Make no mistake: A CCD camera, even the smallest one, can run circles around a DSLR when it comes to faint detail. For this reason, and because a CCD camera has the ability to take data through discrete filters with ease, the CCD camera is my choice for astrophotography. There are a few things you should know, however, about the common properties of these cameras.

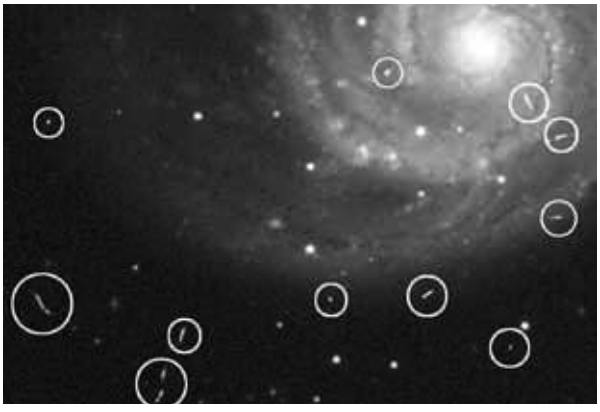
First, CCD chips perform linearly. You can plot the data collection as a straight line. CCD cameras are not perfect, however. As an exposure progresses, current builds up in the chip's individual pixels. This excess — called "dark current" — shows up as bright dots on an otherwise black background. So even in total darkness, a CCD chip produces an image.

All is not lost, however, because you can re-create dark current and subtract it from the data you collected. Imagers refer to this process as "dark subtraction" because you record a "dark frame" in total darkness (with the CCD chip covered) so you capture only the dark current. Once you do this, what's left is the real data — your image.



Dark subtraction is a process astroimagers use to remove bright dots resulting from excess current that builds up in the pixels of a CCD chip. To perform a dark subtraction, take an image (called a dark frame) with the CCD camera covered. Then, using software, subtract that image from your original. All images: Tony Hallas

CCD cameras are so sensitive that they actually record cosmic-ray hits! These show up as optical "debris" scattered throughout your image. Because this pattern is random, it will be different on each of your frames. (Imagers usually combine a number of exposures called "frames" into a final image.) This randomness allows us to eliminate the cosmic-ray noise by using a software algorithm that compares all the frames. Anything constant to all frames remains, and anything random is rejected. The "median combine" and the "standard deviation sigma combine" are examples of two algorithms imagers use for this purpose.



Cosmic rays strike CCD chips during exposures, and most chips are sensitive enough to record the hit as optical "noise" (circled). Most astroimaging software offers an algorithm that will let you easily remove all traces of cosmic-ray hits.

A third noise is optical. Any dust present on a filter or on the CCD camera's window (if it has one) appears on the image as a donut or a black blob. Your optical system also might create vignetting, which causes the corners of the image to darken. You can fix both of these problems by shooting a "flat field" frame, which consists of an image of a (usually) white surface. Software then divides each pixel of the image by the corresponding amount of light collected on the blank image. When you apply this correction, the shadows largely disappear.

So, to summarize, take three steps to achieve clean images with a CCD camera. First, shoot dark frames at the same time and temperature as the data frames. Then apply them to the image to remove dark current. Second, shoot flat field frames to remove optical noise.

Finally, combine several frames of your image together with a median or standard deviation sigma combine algorithm to reject cosmic-ray hits. Note that your dark frames also get hit by cosmic rays, so you'll have to perform a combine on them as well.

Use these techniques and you'll get the most out of the CCD images you capture through your telescope. Next month, I'll talk about combining images and managing the signal-to-noise ratio.

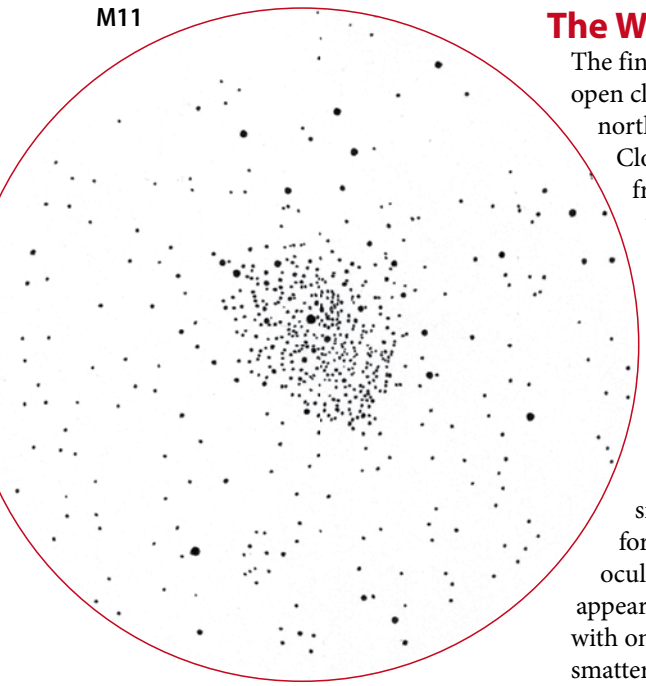
And don't forget to send your best image to *Astronomy*'s 2010 Astroimaging Contest. You have until October 1. For more information, read David J. Eicher's editorial on page 8 of this issue.

Browse the "Imaging the cosmos" archive at www.Astronomy.com/Hallas.

Astronomy's *editor sketches two of his favorite objects.* **by David J. Eicher**

The Wild Duck Cluster and NGC 6781

M11



The Wild Duck Cluster sketched by David J. Eicher using an 8-inch f/10 SCT at 100x.

The Wild Duck Cluster (M11)

The finest sight in Scutum is the brilliant open cluster M11, which lies on the northern edge of the Scutum Star Cloud. Discovered in 1681 by Gottfried Kirch at the Berlin Observatory, M11 was then described as being a "small, obscure spot with a star shining through and rendering it more luminous." It is actually a large, rich, relatively distant open cluster composed of at least 870 stars brighter than magnitude 17.

At first glance, observers with small telescopes may mistake M11 for a globular cluster. Through binoculars and finder scopes, the group appears as a misty clump of nebulosity with only a hint of resolution — a grainy smattering of barely perceivable points of light. A 3-inch telescope at high power shows M11 as a patch of tiny, faint stars some 10' wide with one bright standout star near the group's center. Larger scopes clearly show M11's triangular shape and numerous glittering stars, an impressive sight that the English observer Admiral William Henry Smyth likened to a group of wild ducks in flight.

M11

R. Jay GaBany

Designations: M11, NGC 6705
Position: 18h51m, –6°16' (2000.0)
Constellation: Scutum
Magnitude: 5.8
Size: 14.0'
Distance: 6,200 light-years

NGC 6781

Adam Block/NOAO/AURA/NSF

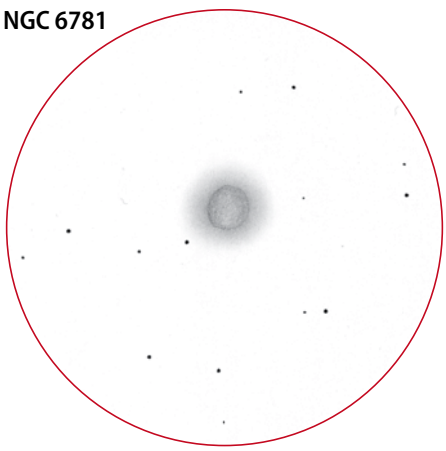
Designation: NGC 6781
Position: 19h18m, 6°32' (2000.0)
Constellation: Aquila
Magnitude: 11.8
Size: 109"
Distance: 2,600 light-years

NGC 6781

Unlike Scutum, nearby Aquila contains numerous planetary nebulae observable through backyard telescopes. The best is NGC 6781, a ring-shaped nebulosity glowing at magnitude 11.8. NGC 6781 measures some 109" (nearly 2') across, so its surface brightness is low. Observe it using medium powers on a dark, transparent night. Under those conditions, you should pick it up through a 4-inch telescope with little trouble.

Large scopes provide a stunning view of NGC 6781. On a night of exceptional seeing and transparency, a 20-inch scope reveals the sharp ring of the nebula and a few faint stars near and inside it (perhaps even the dim blue central star that glows at magnitude 15). With averted vision (glancing slightly away from the object and using your eye's sensitive rods), you may see parts of the ring are brighter than others. You will definitely see that the inner portion of the disk is less luminous than the surrounding ring.

NGC 6781



NGC 6781 sketched by David J. Eicher using a 17.5-inch f/4.5 reflector at 71x.

David J. Eicher *is the editor of* Astronomy. *He has observed and sketched deep-sky objects for 34 years.*

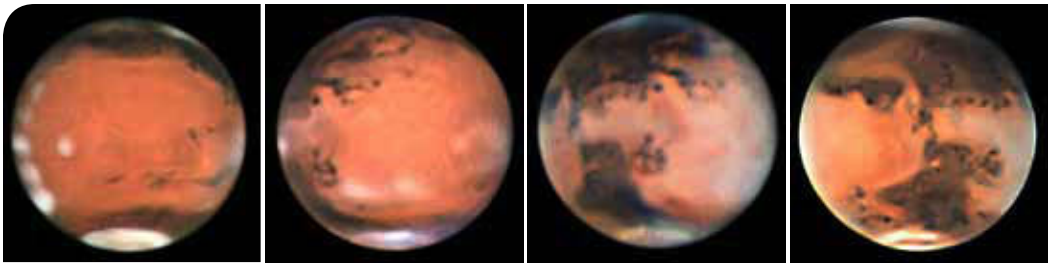
reader gallery

Sharpless 2–129 (7.2-inch Takahashi Epsilon 180 apochromatic refractor at f/2.8, SBIG STL-11000M CCD camera, Hydrogen-alpha/RGB image with exposures of 720, 120, 120, and 100 minutes, respectively) • Keith Schlottman, Tucson, Arizona

Comet 81P/Wild 2 is a periodic comet with a 6-year orbit. In January 2006, NASA's Stardust spacecraft collected and returned to Earth particles from Wild 2's coma. (12-inch ASA Astrograph at f/3.6, FLI MicroLine 8300 CCD camera, LRGB image with exposures of 10, 15, 10, and 15 minutes, respectively, taken April 10, 2010, beginning at 23h16m UT from Farm Tivoli, Namibia) • Gerald Rhemann, Vienna, Austria

We've spotted Bigfoot

In the e-mail accompanying his image submission to *Astronomy*, astroimager Keith Schlottman said that emission nebula Sharpless 2–129 reminded him of a "Bigfoot" print. Thus, he calls it the Bigfoot Nebula, and we certainly see the resemblance. Ultra-faint Sh 2–129 lies in the northern constellation Cepheus the King, 2.8° south-southwest of magnitude 2.5 Alderamin (Alpha [α] Cephei). Not an object for visual observers, it took Schlottman 17 hours and 40 minutes of total exposure to create this image of Sh 2–129.



◀ **Mars shone its brightest** for the year around its opposition January 29. At the time of these images, the Red Planet stood in front of the stars of Cancer the Crab. (16-inch Newtonian reflector at f/22, SKYnyx 2-0 CCD camera, RGB images through Astrodon filters with various exposures) • Donald Parker, Coral Gables, Florida

The young Moon was barely visible as it set behind the silhouetted Italian Alps. The imager captured our satellite when it was only 21 hours and 18 minutes past New Moon. (Canon EOS 100D DSLR, EF-S55-250mm 4-5.6 IS lens at 250mm and f/5.6, ISO 100, 0.4-second exposure, taken March 16, 2010, at 7:19 P.M. local time from Turin, Italy) • Stefano de Rosa, Turin, Italy

▲ **Spiral galaxy NGC 3628** is one-third of the famous Leo Triplet of galaxies. Astronomers think this edge-on starburst galaxy encountered the nearby spiral M66 some 800 million years ago. (10-inch Cave Newtonian reflector, SBIG ST-8XME CCD camera, LRGB image with exposures of 650, 620, 640, and 720 minutes, respectively) • David Doctor, Amherst, Massachusetts

▶ **Open cluster NGC 752** in Andromeda shines at magnitude 5.7 and measures a whopping 50′. Through 10x70 binoculars, you'll count three dozen stars. (6.2-inch Astro-Physics StarFire EDF refractor at f/7.5, SBIG ST-10XME CCD camera, LRGB image with exposures of 60, 36, 36, and 36 minutes, respectively) • Anthony Ayiomamitis, Athens, Greece

reader gallery

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, and exposure information. Submit images by e-mail to readergallery@Astronomy.com.

This spectacular aurora blazed in the sky above northern Canada in August 2004. Aurorae (also called northern and southern lights) occur when charged particles from the Sun, drawn in by Earth's magnetic field, interact with our atmosphere high above the poles. The particles impart energy to nitrogen and oxygen atoms, and when the atoms release the energy, they emit light. (Canon 1Ds Mark 3 DSLR, 16-35mm lens at f/2.8, ISO 400, 10-second exposure, taken August 8, 2004, from Eagle Plains in the Yukon Territory) • Robert Postma, Whitehorse, Canada

Explore the Science behind Science Fiction

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Impossible: Physics beyond the Edge uses this ingenious approach in 24 delightful lectures that will entertain and nourish your mind, all while teaching you more about physics than you ever imagined. Your guide into the realms of the impossible is Professor Benjamin Schumacher of Kenyon College, a pioneering theorist in quantum information, a field dealing with things once deemed "impossible."

Thanks to today's science-fiction-rich media, imaginary creations such as perpetual motion machines and warp-drive space technologies seem like realities. This course serves as an enlightening corrective to this outlook. On the other hand, modern physics is filled with real phenomena that are so counterintuitive they seem like science fiction. Here are a few you'll encounter in these lectures:

- **near-absolute zero**
- **time dilation**
- **quantum tunneling**
- **entanglement**

Designed for those with no previous knowledge of physics, **Impossible: Physics beyond the Edge** will also appeal to the spirit of whimsy and adventure in those already well grounded in the subject.

By the conclusion of this course, you'll have probed the nature of the impossible from many points of view and in many branches of physics. You'll also discover that racing a

U.S. Navy photo by Ensign John Gay.

light beam, hovering over a black hole, chasing quantum particles, trying to reverse the flow of time, and other astounding adventures make for an excellent education in the fundamental laws of nature.

About Your Professor

Dr. Benjamin Schumacher is Professor of Physics at Kenyon College, where he has taught for 20 years. One of the founders of quantum information theory, he introduced the term "qubit," invented quantum data compression, and established several fundamental results about the information capacity of quantum systems. For his invaluable contributions, Professor Schumacher won the 2002 Quantum Communication Award—the premier international prize in the field.

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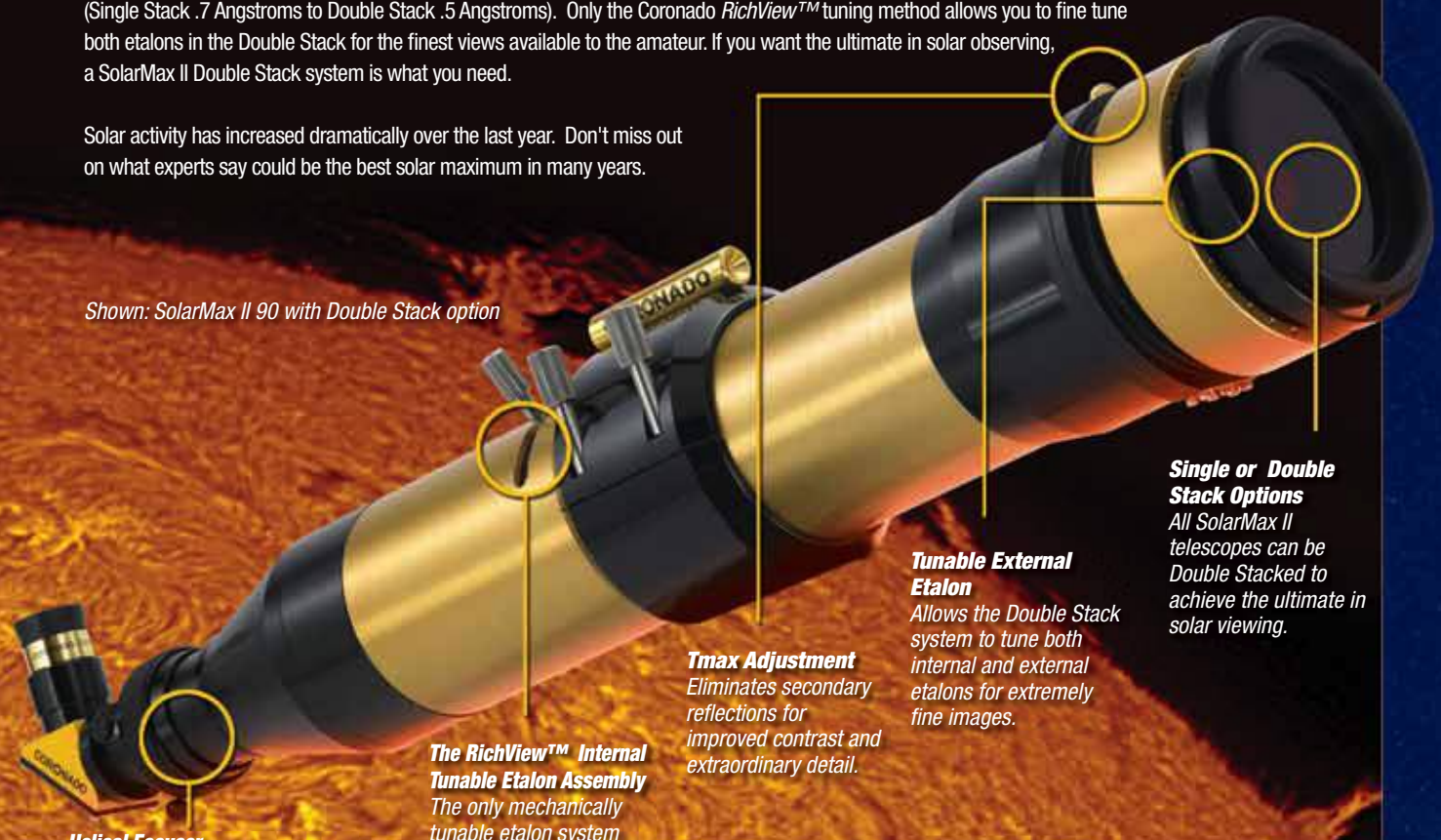
Shown: SolarMax II 90 with Double Stack option



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